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ALPINE SOILS OF THE SUNSHINE AREA, CANADIAN ROCKY MOUNTAINS

by

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A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Alpine Soils of the Sunshine Area, Canadian Rocky Mountains" submitted by Leonard Joseph Knapik in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

This study was intended to provide morphological and analytical data to characterize the alpine soils of the Sunshine area and to relate these soils to their environment.

The alpine soils have organic turf layers overlying dark colored Ah horizons and often Bm horizons of varying description. Volcanic ash in the A and B horizons contributes to silt loam textures and content of amorphous colloids. Underlying till and colluvial materials are of sandy loam texture.

Alpine Dystric Brunisols are widespread in the rolling alpine divide area under *Phyllodoce glanduliflora* and *Antennaria lanata* community types. Alpine Eutric Brunisols were found associated with the Alpine Dystric Brunisols but more often occur on the higher, steeper slopes in association with Orthic Regosols under *Dryas hookeriana* and *D. hookeriana - Carex scirpoidea* community types. Alpine Eutric Brunisols also occur on high wind-exposed slopes under *Kobresia myosuroides* community types. Orthic Regosols are the typical soils in late snowbed areas under *Saxifraga lyallii* cover. Cumulic Regosols occur on alluvial deposits under *Salix barrattiana* and on steep slopes under *Anemone occidentalis* community types. Gleysolic soils are present in poorly drained areas under *Eriophorum scheuchzeri, Eriophorum angustifolium,* and *Carex* spp. community types. Earth hummocks with their cryoturbated soils are present in isolated areas.

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INTRODUCTION

Soils in high mountain areas have received relatively little attention by pedologists. This was due to a lack of economic importance and general inaccessibility of the areas. The increasing recreational use of mountainous areas and concern for protection of the environment has created a demand for information concerning alpine soils and the relationship of these soils to their environment.

This study was conducted in connection with a program of the Canadian Wildlife Service, Department of the Environment, to characterize alpine ecosystems of the Canadian Rocky Mountains in order to provide information for management of alpine areas in the mountain National Parks.

The objectives of this soils investigation were (1) to provide morphological, physical, chemical and mineralogical data to characterize the alpine soils of the Sunshine area, and (2) to relate soil properties and soil genesis to the environment.

The approach taken was to describe in detail and sample soil pedons characteristic of soils occurring under several plant communities in an alpine area. The samples were then subjected to physical, chemical, and mineralogical analysis in the laboratory.

The study area, known locally as "Sunshine", is located approximately 16 km southwest of Banff, Alberta (Figure 1) along the Continental Divide in the eastern fringe of the Main Ranges of the Rocky Mountains.

The soils were described and sampled in August, 1970 and laboratory investigations were completed by 1972.

Figure 1. Location of Project Area.

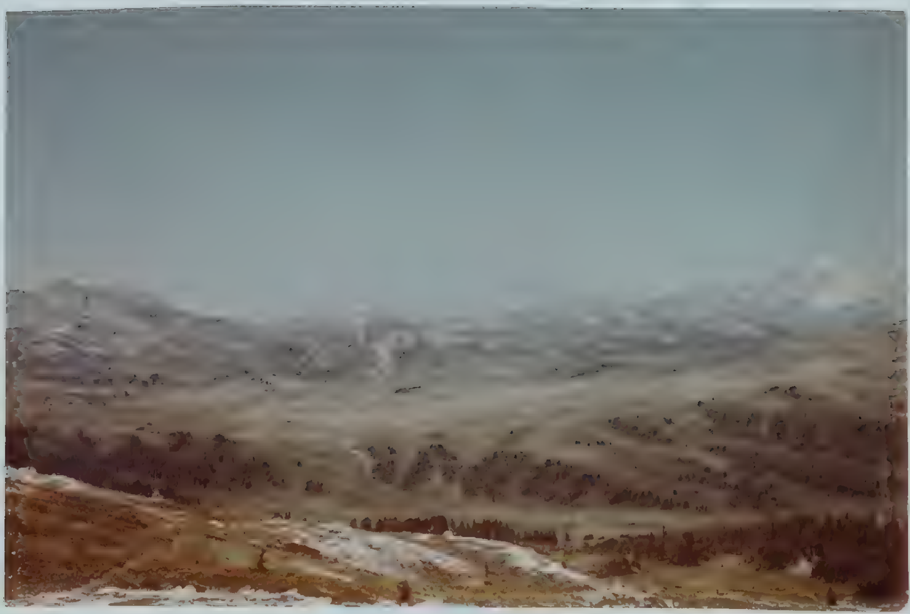


PLATE 1. Photograph of study area

This view of the Sunshine area from the south shows the rolling alpine divide (photo center), Twin Cairns Mountain on the left, and Wa-Wa Ridge in right center. Aug. 10, 1971.

PART I LITERATURE REVIEW

Definition of the Term Alpine

The term alpine has been used to describe various ecosystems and geographical regions (Daubenmire, 1943; Major and Bamberg, 1968; Love, 1970; Baig, 1972; Troll,1972a, 1972b), which has led to some confusion. As used here, alpine may be defined physiognomically as the area above the line where trees retain normal growth form and below the permanent snow line. Thus coniferous trees that exhibit krummholz form (a layered, stunted growth form) may occur in the alpine zone. This use of the term alpine is similar to that used by Hrapko (1970) and Kuchar (1972a) to describe areas in Jasper National Park. A vegetational zone that commonly exists between the continuous subalpine forest and the treeless alpine, characterized by clumps or islands of conifers surrounded by tundra vegetation, is often separated as a distinct zone. This zone has been named the forest-tundra ecotone (Weaver and Clements, 1938; Marr, 1961, 1972), the upper subalpine (Spilsbury and Tisdale, 1944), and the timberline zone (Daubenmire, 1943). This zone has been included as part of the alpine zone for the purposes of this study.

Alpine regions have distinct flora, fauna, climate, landforms and soils (Moss, 1955; Marr, 1961; Wright and Osburn, 1968).

The Alpine Soil Environment

The extreme variation in topography, climate, and vegetation combined with the many types of parent material present, results in complex soil patterns in alpine areas (Retzer, 1948, 1956; Johnson and Cline, 1965).

Climate is probably the most significant soil forming factor in the alpine as the cold temperatures and short growing season result in reduced energy being available to the soil system and a short active period of soil formation (Volobuev, 1964; Nimlos, McConnell and Pattie, 1965; Terjung, *et al.*, 1969).

In mountainous areas temperature decreases with increasing altitude due to an adiabatic lapse rate (Baker, 1944; Marr, 1961; Bamberg and Major, 1968), however this correlation may be modified by topography and aspect. For example, north- and northeast-facing slopes are cooler than south-facing slopes in the northern hemisphere (Shreve, 1924; Cantlon, 1953) and temperature inversions often occur in mountain valleys (Baker, 1944; Beder, 1967; James, 1968). The dominance of low temperatures is reflected in the occurrence of permafrost in alpine areas of Alberta (Ogilvie and Baptie, 1967), British Columbia (Matthews, 1955) and in Colorado and Wyoming (Retzer, 1956, 1965; Johnson and Billings, 1962; Johnson and Cline, 1965).

Soil development seems to be further limited by low moisture availability in well-drained soils during the time of maximum temperatures (Nimlos, McConnell, and Pattie, 1965; Retzer, 1965; Bliss, 1966). As altitude increases precipitation generally increases (Marr, 1961; Bamberg and Major, 1968), however the percentage of total precipitation that falls as snow may also increase (Ogilvie, 1969). Due to strong winds the snow is distributed unevenly, varying from snow-free ridges to snowbank areas with deep snow accumulation that may remain throughout the summer (Marr, 1961; Holway and Ward, 1963; Nimlos and McConnell, 1965; Bamberg and Major, 1968). This irregular accumulation of snow is

important in governing freeze-thaw cycles of the soil, needle ice erosion, and moisture regime (Bamberg and Major, 1968). Vegetation patterns are often governed by depth and duration of snow cover (Billings and Bliss, 1959; Beder, 1967; Hrapko, 1970; Trottier, 1972). The importance of snow cover in the cycling of matter and energy, and especially in trapping aeolian material has been shown by Warren Wilson (1958), Billings and Bliss (1959), Marr (1961) and Stepanov (1962).

The cool temperatures and short snow-free period cause retardation of chemical weathering processes and biological activity in the soil. This results in slow rates of pedological transformations and transfers reflected by the accumulation of organic matter in surface horizons and poorly differentiated mineral horizons in alpine soils (Nimlos and McConnell, 1962, 1965; Duchaufour, 1965; Retzer, 1965). The physical condition of the soils is strongly affected by frequent freeze-thaw cycles (Troll, 1944).

The quantity and quality of light radiation varies with altitude. Direct radiation increases with altitude by diffuse radiation decreases. A discussion of high mountain radiation climates is given by Bamberg and Major (1968).

The strong influence of climate on alpine ecosystems is reflected by plant distributions such as the location of timberline. Griggs (1946) states that timberlines in the Rocky Mountains are tension zones with specific location a result of wind direction and intensity. Costin (1968) relates timberlines around the world to the $10^{\circ}C$ isotherm for the warmest month. Precipitation, snow depth, and such non-climatic

factors as snowslides and landslides, geological substratum, fire, soils, and biological agencies (including man) also influence timberline location (Lewis, 1923; Daubenmire, 1955; Heusser, 1956; Bamberg and Major, 1968; Ogilvie, 1969; Baig, 1972).

Alpine vegetation, composed dominantly of herbs or decumbent shrubs, is adapted to the harsh environmental conditions. Most plants are low growing to escape the high wind velocities (Holch, *et al.*, 1941; Warren Wilson, 1959) and to obtain heat from the soil. The plants are adapted to cold temperatures and desiccation and some are adapted to very late snow cover (Marr, 1961).

The flora above timberline is composed of alpine and arctic species of circumpolar distribution, of cordilleran species, and of boreal and plains species of wide ecological amplitude. The kinds of vegetation and low temperatures favor incorporation of large amounts of organic matter in surface horizons of alpine soils (Retzer, 1956, 1965; Nimlos and McConnell, 1965). This is an important factor in soil formation due to the role organic derivatives play in pedogenesis (Konanova, 1966). Duchaufour (1965) reports the cool, moist climate in European alpine areas favors ericaceous and resinous vegetation that yields a very acidic humus.

The moderating effect of topography on local climate has already been discussed. The steep slopes usually present in high mountain areas results in several modifying processes acting on the soil bodies. Mass wasting processes shift material downslope thus truncating and burying soil profiles (Uziak, 1963; Benedict, 1970). Amen (1966) showed that plant regeneration was significantly influenced by slope

rejuvenation of soils. Harris (1972) measured 323 mm horizontal displacement in a three-month period of soil creep at Vermillion Pass, Alberta. Soils which are more fully in equilibrium with their environment occur on terraces and gentle slopes with more weakly-developed soils on steeper slopes (Duchaufour, 1965).

Various patterned ground features including terraces, solifluction lobes, stone polygons, stone stripes and earth hummocks have been reported for several alpine areas (Sharp, 1942; Washburn 1956; Billings and Mooney, 1959; Billings and Mark, 1961; Johnson and Billings, 1962; Baptie, 1968; Bryant and Scheinberg, 1970; Knapik and Landals, 1972). These features provide a changing microtopography that affects snow distribution and moisture regime which in turn governs vegetation and soil patterns. Benedict (1970) did an extensive study on the occurrence and movement of solifluction lobes, "*Dryas*-banked terraces", and "*Dryas* stripes" in Colorado.

Steeply sloping topography causes rapid runoff of snowmelt and rainfall and sloping bedrock that is close to the surface controls subsurface water movement.

Parent materials are extremely variable and often mixed in the mountains. Due to orogenesis, folded and faulted beds of igneous, sedimentary, and metamorphic rocks may all be present over a short distance, as well as recent deposits of glacial till, colluvium, alluvium, and aeolian materials. Due to glacial action, mass wasting, and frost action, these materials are often churned up and mixed together (Retzer, 1948; Johnson and Cline, 1965).

The effect of parent material on soil formation in the alpine

environment has been reported by Duchaufour (1965) to be of less significance than climate, vegetation and topography. He states that differences between soils developed on calcareous and non-calcareous rocks can only be noticed when conditions are favorable.

Retzer (1965) and Nimlos and McConnell (1965) reported soils developed from calcareous rocks to have different texture, pH, fertility, and erodibility than those developed from acid rocks. Generally shales tend to produce finer textured soils than sandstones. Coarse fragment content varies widely with parent material but is usually high (Retzer, 1965; Nimlos and McConnell, 1965).

The presence of volcanic ash in the soils has several pedological implications (Baptie, 1968; Beke, 1969; Van Ryswyk, 1969; Pettapiece, 1970; Beke and Pawluk, 1971; Pettapiece and Pawluk, 1972). Volcanic ash occurrence in the Canadian Rocky Mountains has been recorded by Heusser (1956), Rutter (1965, 1972), and Westgate and Driemanis (1967). Ash from at least four sources is present in the Rocky Mountains (Westgate, Smith and Tomlinson, 1970) however ash from Mount Mazama (Crater Lake), Oregon dated at 6600 years B.P. (Westgate, Smith and Tomlinson, 1970) seems to be the most prevalent in the Banff area.

Previous Alpine Soils Investigations

Several studies have been undertaken in alpine areas of the Canadian Rocky Mountains in recent years that have included investigations of the soils present.

Baptie (1968) and Trottier (1972) correlated alpine plant communities with their characteristic soil profiles. Baptie (1968)

reported the occurrence of Orthic Podzols, Podzo Regosols, Rego Black Chernozems and Alpine Brown soils under alpine plant communities in Snow Creek Valley, Banff National Park. Trottier (1972) described Alpine Eutric and Dystric Brunisols, Gleyed Alpine Dystric Brunisols, Orthic and Cumulic Regosols, and Orthic Humic Gleysols at Highwood Pass in the Kananaskis area.

Baig (1972) studied the ecology of timberlines in Alberta. He reported the predominance of Orthic Humo-Ferric Podzols at several timberline locations in Banff and Waterton National Parks.

Beke (1969) reported a vertical sequence of soils in the Kananaskis area from subalpine to alpine. He classified the alpine soils as Alpine Dystric Brunisols and Orthic and Cumulic Regosols. Soil characteristics became less pronounced with elevation.

Jeffrey, Bayrock, Lutwick and Dormaar (1968) discussed land-vegetation typology in the Upper Oldman River Basin, Alberta. They found Mull Regosols to be the zonal soils on both calcareous and non-calcareous materials at high elevations.

Pettapiece (1970, 1971) working in the North Saskatchewan River Valley in the Front Ranges of the Rocky Mountains reported Dystric Brunisols, Lithic Orthic Regosols and turfy alpine soils above timberline.

Hrapko (1970) included soil moisture and texture analyses as part of an ecological study of plant communities on Signal Mountain in Jasper National Park.

Kuchar (1972b) has reported descriptions and analytical results for alpine soils at Mt. Edith Cavell and has unpublished data for

alpine soils on the Bald Hills (pers. comm) in Jasper National Park.

Root and Knapik (1972), Kregosky, *et al.*, (1972) and Knapik and Landals (1972) investigated the limitations of alpine and subalpine soils for hiking trails along the Great Divide Trail Route and have described and classified the soils along the route.

Bryant and Scheinberg (1970) briefly described soils on Plateau Mountain, Alberta as part of a study of vegetation and frost activity in an alpine fellfield.

Van Ryswyk (1969) compared forested soils at the upper limit of timberline with adjacent alpine soils in the Cascade Mountains of south-central British Columbia. The soils were mapped, with map units being placed into three major groups, based on profile characteristics. The three major groups were (1) Podzol, (2) Alpine Brown, Continuous Ash and, (3) Alpine Brown Discontinuous Ash.

Sneddon, Lavkulich and Farstad (1972) related physical, chemical and mineralogical data to the morphology and genesis of alpine soils in the Coast Mountains and Interior Plateau of southern British Columbia. They classified the soils at four sites as Mini-and Orthic Humo-Ferric Podzols and an Alpine Dystric Brunisol.

Numerous studies of alpine soils have been carried out in the Rocky Mountains of the United States.

Retzer (1948, 1956) was the first to report detailed information on alpine soils in North America. He stressed the importance of low temperature and short growing season in these "cryopedogenic regions". He reported profile morphology to be distinctive but weakly developed. Well-drained soils were described as having turf layers (Ao) overlying

Ah(A1) horizons with high organic matter content, low bulk density, low C/N ratio, weak structure, and loose consistence. Silt and clay content decreased and pH increased with depth. In 1956 Retzer suggested three great soil groups to handle the classification of alpine soils, the separations being based mainly on drainage. The three great groups were Alpine Turf (well drained), Alpine Meadow (imperfectly to poorly drained soils with a mineral surface horizon) and Alpine Bog (poorly drained soils with a peaty surface horizon). These great groups have been concisely defined by the Western Regional Soil Survey Work Group (1964) and have been used by several researchers in North America. Retzer (1965) later recommended the great group name Arctic Brown to classify the well-drained alpine and arctic soils that he feels are very similar.

Nimlos and McConnell (1962, 1965) working in Montana, reported genesis of alpine soils to be mainly an incorporation of organic matter in the surface horizons with some sesquioxide and humus eluviation in acid materials, and some recrystallization of carbonates in calcareous materials. They reported rooting to be confined to the upper foot of the soil, comprising the turf and Ah horizons. They listed chemical, physical and mineralogical data for three soils series, differing in drainage and parent material. Nimlos, McConnell and Pattie (1965) reported soil temperatures and moisture regimes for three alpine stand types in Montana. These were fellfield, dry meadow and sedge-hummock, representing a gradient from dry to moist conditions. Mean summer air temperature was 7.2°C (45°F), with surface soil horizon temperatures being close to this, and decreasing with increasing moisture content.

Moisture availability varied from a summer moisture deficiency in the fellfield to a moisture surplus in the sedge-hummock stand type.

Johnson and Cline (1965) described the alpine soil climate in the mountains of Northern Colorado as being cold and moist, with an average annual soil temperature of -2.2 to $0^{o}C$ ($28-32^{o}F$). Soils of major occurrence in alpine areas were Alpine Turf (Cryorthods), Alpine Meadow (Cryaquods), Lithosols (Lithic Cryorthents), and Chernozems (Borolls). Johnson and Billings (1962) stressed the importance of cryopedogenic processes in the formation of alpine soils on the Beartooth Plateau of Wyoming and Montana.

Several ecological studies of alpine ecosystems have involved the relationship of environmental parameters, including soil properties, to the distribution and functioning of plant species (Bliss, 1956, 1963, 1966, 1971; Billings and Bliss, 1959; Marr, 1961; Bliss and Woodwell, 1965). Douglas and Ballard (1971) examined soils under krummholz and heath vegetation in the North Cascades of Washington. Typical soils were Lithic Humo-Ferric Podzols under krummholz and Lithic Mini Ferro-Humic Podzols and Lithic Alpine Dystric Brunisols under heath vegetation.

European alpine areas have received extensive study and soil development sequences and soil morphology have been reported for various alpine areas, mostly in the Alps (Braun-Blanquet and Jenny, 1926; Troll, 1944; Kubiena, 1953; Dahl, 1956; McVean and Ratcliffe, 1962; Duchaufour, 1965). Extrapolation of conditions in European alpine ecosystems to those in North America must be done with care, keeping in mind the differences in local climate and vegetation

(Major and Bamberg, 1968; Troll, 1972a, 1972b). Kubiena (1953) included alpine soils in his soil classification scheme. Several of the findings of European workers have been discussed in earlier sections of this literature review.

Bedrock Geology Map Legend

Quaternary:	alluvium, colluvium, till (bedrock deeply covered)
Mississippian:	limestone, dolomite, calcareous shale and siltstone
Devonian:	limestone, dolomitic limestone and dolomite
Ordovician:	dolomite, limestone and minor chert and shale
Cambrian and Ordovician:	calcareous shale and limestone
Cambrian:	limestone, shale, siltstone, dolomite
Lower Cambrian:	(Gog Group) quartz sandstone, siltstone
Precambrian:	(Miette Group) quartz sandstone, slate, and quartz pebble conglomerate

Thrust fault (teeth on upthrust side)

Other faults

Geological boundary

Syncline

PART II PHYSIOGRAPHY

Geology

Bedrock Structure and Lithology

The Sunshine area is located in the eastern fringe of the Main Ranges structural subprovince of the Canadian Rocky Mountains section of the North American Cordillera physiographic province (McConnell, 1887; North and Henderson, 1954; Price, 1971).

Bedrock geology of the Banff area was recently mapped as part of the Bow-Athabasca project of the Geological Survey of Canada. The bedrock map (Figure 2) of the study area is taken from the GSC map series, Map 1294A (Geology Banff, East Half) and Map 1295A (Geology Banff, West Half) prepared by Price and Mountjoy (1972a, 1972b).

Bedrock structure in the area is complex. Due to folding and faulting several formations and facies are present and most of the bedding is steeply inclined. Calcareous strata of Paleozoic age predominate in the area with limited occurrences of non-calcareous strata of Lower Cambrian and Precambrian age.

Dip slopes of large thrust blocks on the eastern edge of the study area consist mainly of Upper Devonian limestones and dolomites. Inclined beds of Devonian, Ordovician and Cambrian limestones, dolomites and shales underlie much of the remainder of the area. Lower Cambrian (Gog Group) quartz sandstones outcrop on Quartz Hill and to the west of the study area. Precambrian (Miette Group) outcrops form Wa-Wa Ridge and outcrop on Quartz Hill. Lithology consists of quartz sandstones interbedded with slates and quartz pebble conglomerates.

Figure 2. Bedrock Geology Map.

PLATE 2. Photograph of study area

The steep windswept dipslope of Lookout Mountain rises above the forest-tundra ecotone in the foreground. The chairlift standards and trails are evidence of the recreational use of the area. Aug. 9, 1972.

Geomorphology

The central part of the study area is essentially a high "plateau" or alpine divide with undulating to rolling topography (Plate 1). Elevation varies from 2240 m (7400 feet) to 2360 m (7800 feet) which is some 600 to 900 m higher than the major valley floors in the area. The east side of the study area consists of the dip slopes of large thrust blocks thrust to the northeast (Lookout and Eagle Mountains) with peaks attaining altitudes of almost 3000 m (Plate 2). Wa-Wa Ridge (2450 m), Twin Cairns (2500 m) and Quartz Hill (2560 m) form the western and southern boundaries of the study area.

Topography is controlled principally by structure of the bedrock modified by glacial erosion and deposition, and to lesser degrees by mass wasting, fluvial, and differential weathering processes.

Glaciation

The study area was glaciated during Pleistocene times as evidenced by the glacial till deposits that cover much of the area (Plate 3). There seems to have been very little ice movement across the Continental Divide in this region of the Rocky Mountains (Rutter, 1965) so the glacial activity in the Sunshine area was likely a result of local ice accumulation and movement. There are two cirques on the north side of Lookout Mountain and one on the north side of Eagle Mountain. Intermittent streams head in these cirques and a rock glacier occupies one cirque on the north side of Lookout Mountain. Sunshine Creek valley from the Continental Divide north to Healy Creek has been sculptured by ice flow as the cross-profile of the valley is rounded with gently sloping sides, typical of a glacial channel rather than of

a stream-cut valley. Deglaciation probably occurred in the order of 9000 years ago, at about the same time as retreat of the ice from the Bow Valley (Rutter, 1965, 1972).

Till deposits form a thin mantle over much of the study area, with depth being controlled by bedrock topography. In many places the till is less than one meter thick and it has often been moved by soil creep and frost action processes. The till has a high content of coarse bedrock fragments and is of a sandy loam to loam texture. Glacial lacustrine deposits occur to limited extent in depressional areas, with textures ranging from silty clay loam to clay.

Postglacial Features

Colluvial Deposits - Colluvium consists of weathered rock material that has been moved and deposited mainly by the force of gravity. Glacial till materials that have been extensively moved and re-deposited by slope movement processes since glacial deposition are also classified as colluvium for the purposes of this study. Colluvial deposits are prevalent in the area, especially at higher elevations and on steep slopes. Colluvium is typically coarse textured with high contents of angular rock fragments.

Aeolian Deposits - Wind-deposited materials are evident in the sola of many of the soils. This material may occur as layers or lenses but is usually mechanically mixed with till and colluvium. The aeolian material contains varying amounts of volcanic ash. This ash was observed in several locations as distinct layers and lenses but it is generally mixed with other materials due to soil creep and frost action. Deposits of ash of up to 1 m in thickness were observed in four

locations under earth hummocks. Ash from one of these locations (T-23) was identified as being of Mazama origin (Westgate, pers. comm., 1972)[1], which is dated at 6600 years B.P.

Fluvial Features - The Healy Creek, Simpson River, and Howard Douglas Creek valleys are much lower than the Sunshine alpine area due to bedrock structure and strong glacial erosion of the larger valleys. As a result streams in the area drop 600 to 900 m in a distance of 3 to 5 km. A stream with such a gradient would be expected to be down-cutting rapidly. Sunshine Creek, in a hanging valley, is eroding rapidly to reach its local base level and now displays several nick-points in the form of small waterfalls.

Alluvial deposition is occurring in several locations where runoff from steep slopes encounters more gentle gradients and dumps sediment, often in basins where larger creeks head.

Mass-wasting Products and Frost Features - Mass-wasting involves the bulk transfer of masses of rock debris down slopes under the direct influence of gravity (Thornbury, 1969). Alpine areas are especially susceptible to mass-wasting processes due to the light or discontinuous vegetal cover, steep slopes, large diurnal and seasonal temperature fluctuations, and heavy snowfall.

Disturbed soil profiles and terraced slopes are evidence of active soil creep. Soil profiles are often truncated and may lack distinctive horizon differentiation due to movement. Creep is most active on steep slopes in shaded and lee positions, where there is greater moisture availability. Rock creep was noticed especially on the west side of

[1] J.A. Westgate, Dept. of Geology, University of Alberta

Twin Cairns. Large blocks of conglomerate are some distance downslope from the scarp face. Talus slopes are common wherever steep cliffs exist, being most abundant on those cliffs with a north to east exposure as reported for the Lake Louise area (Gardner, 1970). Talus creep occurs in these deposits. A rock glacier occurs in a cirque basin on the northeast side of Lookout Mountain.

Solifluction, the slow movement of water-saturated masses of soil under the influence of gravity, has been reported to be of considerable significance at high altitudes (Thornbury, 1969; Benedict, 1970), but was not felt to be of major importance in the Sunshine area.

Frost action is involved in the formation of patterned ground features as well as being important in soil creep and solifluction. "*Dryas*-banked terraces" (Benedict, 1970) are common micro landforms on exposed slopes and ridges. These are small terraces that have a riser height of 2 to 6 cm and a tread width of 10 to 30 cm. The treads are essentially bare of vegetation, being covered with angular gravel-sized clastics, and the risers are vegetated by *Dryas hookeriana*. These terraces form striped patterns that may be aligned either parallel to, or normal to the slope contours. According to Benedict (1970) these features are formed by the interaction of vegetation, wind, and surficial frost creep.

Earth hummocks, which are a particular form of non-sorted net (Washburn, 1956), occur in several locations. In each of the four locations examined the hummocks occupied small, enclosed depressions (ca. 30 m diameter) with no drainage outlet. The hummocks, approximately 75 cm in diameter and 20 to 40 cm in relief, are formed on deposits of Mazama volcanic ash of up to one meter in thickness. The mounds

and hollows are covered with a uniform mat of *Carex nigricans*.

Stone rings, frost boils, and other patterned ground features have been reported for several alpine areas in the Canadian Rocky Mountains (Baptie, 1968; Bryant and Schienberg, 1970; Kuchar, 1972a, 1972b; Knapik and Landals, 1972) but were not noticed in the Sunshine area to any extent.

The summit of Twin Cairns is covered with large blocks of conglomerate that could be considered as blockfields or felsenmeere. A "rock river" exists on the northeast corner of this ridge where the conglomerate blocks are concentrated into a stream-like flow.

Vegetation

Vegetation of the Sunshine area was investigated by A.E. Porsild during 1945, 1946, 1951, and 1956. He collected approximately 350 species of vascular plants from above the 2120 m (7000 foot) level (Porsild, 1959). G.W. Scotter, with the Canadian Wildlife Service, is presently studying the vegetation in the area. The 54 plots, representing various plant community types, at which the soils investigations for this study were made were established by Scotter and the composition and structure of plant communities were described as part of his study (unpublished).

The unit of vegetation used in this study is the plant community type, which is equivalent to the association of Daubenmire (1960). It is a preliminary designation of stands that have essentially the same dominant species in each strata. Nomenclature of plants is according to Moss (1959).

Climate

The climate of the study area is characterized by long, cold winters and short, cool summers with a winter-high, summer-low distribution of precipitation.

Climatic data from alpine areas are very limited due to problems in maintaining stations and making observations. Data have been collected in the Sunshine area by the Canadian Wildlife Service but have not been condensed and analyzed. Data from the nearest observation sites within the Rocky Mountains with available data, namely Banff and Lake Louise, are shown in Table 1.

Table 1 CLIMATIC DATA FOR BANFF AND LAKE LOUISE

		Temperature (°C)					Precipitation	
			January		July		Mean	% as
Station	Elevation	Mean Ann.	Max.	Min.	Max.	Min.	Ann.	Snow
Banff	1389 m	2.2	-6.1	-16.1	22.2	6.7	475 mm	42
Lake Louise	1525 m	0	-6.7	-21.1	21.7	3.3	782 mm	63

[1] Data from McKay, Curry and Mann (1963).

The trend from Banff, in a wide valley floor in the Front Ranges, to Lake Louise on the Continental Divide is to lower mean annual temperatures and greater mean annual precipitation. Most of the precipitation at Lake Louise occurs as snow from September to May in contrast to Banff where the majority of precipitation occurs as rain

in the summer months.

The Sunshine area is approximately 700 m higher than Lake Louise and is also on the Continental Divide. If an adiabatic lapse rate of $2^{o}C$ per 310 m elevation (Baker, 1944) is valid for this area, mean annual temperature at Sunshine would be about $-2^{o}C$. Data from the Snow Creek Valley alpine area in the Front Ranges to the northeast indicates mean daily summer temperatures of 40 to $50^{o}F$ (4.4 to $10^{o}C$) and mean daily winter temperatures of 10 to $25^{o}F$ (-13 to $-5^{o}C$) (Beder, 1967). Maximum summer temperatures at Snow Creek rarely exceed $70^{o}F$ ($21^{o}C$).

Diurnal temperature fluctuations are extreme during the summer months. Maximum daily temperatures may exceed $20^{o}C$ with minimum temperatures being below freezing. Temperature inversions are common at night as evidenced by data collected at Snow Creek Valley where as many as 30 inversions per month have been observed (Beder, 1967).

Total annual precipitation is probably greater at Sunshine than at Lake Louise due to greater snowfall as evidenced by winter ski reports from the two areas.

Snowfall is distributed unevenly due to drifting by strong winds. Westerly-exposed slopes and ridge crests have light snow cover or may be blown free of snow and snow cover melts early in the season, whereas valleys and north-east facing slopes accumulate great depths of snow. A snow cover of 1 to 4 m persists for 9 to 10 months of the year over most of the area, while snowbeds on some shaded, lee slopes may remain throughout the year (Plate 3). There are approximately 2 months (July and August) between the last heavy snowfall in the spring and the first

PLATE 3. Photograph of study area

Numerous late snowpatches occur throughout the till-covered alpine landscape and on the lee slope of Quartz Hill in right background. Aug. 9, 1972.

heavy snowfall of the fall. Light snowfalls may occur on any day of the year.

Permafrost was not encountered in any of the soil pits (1.5 m maximum depth) however workmen reported the presence of ice in July at about 2.5 m depth at 3000 m elevation on the southwest-facing slope of Lookout Mountain. Permafrost has been reported at Snow Creek Valley in a palsa bog (Ogilvie and Baptie, 1967) and has been reported in several alpine areas of Montana and Colorado but is not considered important for soil conditions in the Sunshine area.

Despite the high moisture reservoir in the snowpack, moisture stress conditions prevail in July and August when temperatures are at a maximum, except in areas of poor drainage or where snowmelt is available late in the season. These conditions are similar to those reported by Nimlos, McConnell and Pattie (1965) for an alpine region in Montana where a moisture deficit was found in well-drained soils.

Winds are very strong and prevalent in the area as evidenced by wind-trained treeform, low-growing vegetation, and wind-eroded ridges and westerly-facing slopes.

PART III FIELD INVESTIGATIONS OF THE SOILS

Methods

Soils were examined in two locations at each of 55 plots, 54 of which were previously established by the Canadian Wildlife Service. The soil body deemed most representative of the plot was described in detail and the alternate soil body was used to estimate variation in soil conditions.

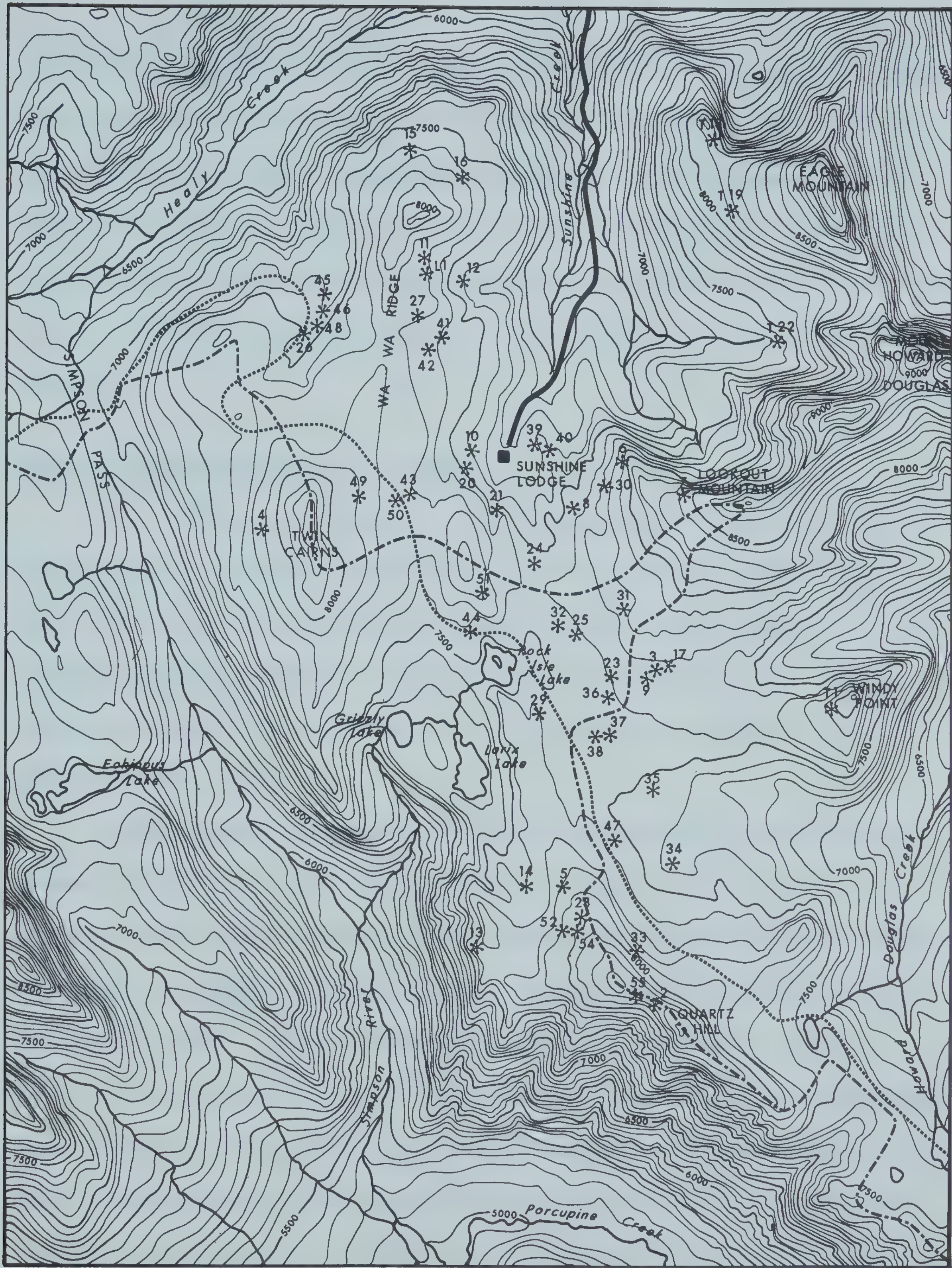
Soil parameters including texture; structure; consistence; root abundance, size and orientation; rooting depth; horizon type, depth, and sequence; coarse fragment content; and effervescence with dilute hydrochloric acid were described using the nomenclature of the Canada Soil Survey Committee (1970). Soil color was described using Munsell Soil Color Charts (1954). The soils were classified according to the Canadian System of Soil Classification (C.S.S.C., 1970).

Major soil horizons of sufficient depth were sampled for physical, chemical and mineralogical analyses.

In addition the site of each plot was described with respect to altitude, slope, aspect, vegetation, drainage conditions, significance and type of geomorphic processes, and the geologic nature and origin of the soil parent materials.

Results and Discussion

Soils of the Brunisolic, Regosolic and Gleysolic Orders were found in the area as well as soils under earth hummocks that were not classified using the System of Soil Classification for Canada (C.S.S.C., 1970). "Nonsoils" that do not meet the minimum depth requirement of 10 cm and



*[7] – Plot T 7
–·–·–·– Continental Divide
·········· Great Divide Trail
━━ Road

1000 0 1000 2000 3000 METRES

Figure 3. Plot Location Map.

bare rock formations are also present in the area. Profile descriptions for each of the 55 soil pedons described and sampled in the field are shown in the Appendix. Locations of sampling sites are presented in Figure 3. Eight of these soils were selected as being representative of many of the soils in the area and descriptions of these are presented in the following sections together with discussion of the other soils examined.

General Characteristics of the Soils

Many features are common to the freely-drained soils of the area. The soils have developed on glacial till and colluvial till deposits that often have aeolian inclusions in the upper 20 cm. (Plate 4.) The aeolian material contains varying amounts of volcanic ash. Due to frost action and soil creep the various parent materials are often mixed together (Plate 5).

A densely-rooted organic turf (L) has developed on most of the soils. This fibrous mat extends into the upper Ah horizon. The Ah horizons are a nonchernozemic, moder type of Ah that have high contents of weakly-decomposed organic material mechanically incorporated into the mineral soil. Color varies from dark brown to black. Bulk densities of 0.6 to 0.8 g cm^{-3} are common. Structure is weak, generally fine granular, and consistence is very friable. Textures are generally silt loam with low (5-15%) clay content. An eluviated Ahe horizon was observed in only one location (L1) within the upper limit of the forest tundra ecotone.

B horizons vary in thickness and are often discontinuous. Colors are dark brown to yellowish brown with textures ranging from silt loam

to sandy loam. Structure is weak, usually fine granular and the soil is friable to very friable. Bulk densities measured varied from 0.6 to 1.2 g cm^{-3}. Due to a lack of evidence of translocation of materials within the profile, these horizons were classified as Bm horizons. Total depth of the A and B horizons averages less than 20 cm.

C horizons usually do not contain significant amounts of the aeolian material that is evident in the sola, thus are often designated as IIC horizons. Textures are loam to sandy loam and are often gravelly due to high contents of coarse fragments (particles greater than 2 mm in diameter). Plant roots penetrate into the C horizons, often reaching depths of 40 cm and occasionally 50 or 70 cm. Rooting depth may be limited by a bedrock contact which often occurs within 50 cm, thus resulting in a lithic classification of several of the soils.

Alpine Dystric Brunisols - These soils are of common occurrence and represent maximum pedogenic development in the area. They tend to occur in areas of relatively stable slopes and moderately early snow release under various alpine tundra communities. Horizon sequence is L, Ah, Bm, C(k)[1], (R). Of the 12 soils identified as Alpine Dystric Brunisols (Table 2) five, namely those at T8, T9, T17, T30 and T39 are underlain by calcareous parent materials. The sola however often contain considerable amounts of non-calcareous aeolian material (including volcanic ash), thus the calcareous C horizons are often considered to be IICk horizons. The other nine Alpine Dystric Brunisols have developed on till or colluvium derived mainly

1 Designations in parentheses indicate horizons which may occur.

Table 2 SITE CHARACTERISTICS OF THE ALPINE DYSTRIC BRUNISOLS

Plot	T9	T17	T8	T30	T11	T13	T16	T15	T49	T50	T42	T36
Elev m	2340	2355	2300	2355	2345	2360	2330	2330	2370	2355	2310	2260
ft	7700	7730	7540	7730	7700	7750	7650	7650	7770	7730	7590	7410
Slope %	8	6	20	35-40	20	20	15	15	5-18	30	15	2
Aspect	SW[1]	W	SW	W	ESE	SSE	NNE	N	SE	SE	SE	-
Drainage	D2[2]	D3	D1	D1	D1	D1	D1	D1	D1	D1	D1	D4
P.M.	A+C/BR[3]	A+C/T/BR	C/BR	C+A	C/T	A/T	A+C	C	A+C/BR	C+A/T	A/T	A/T
P.M. reaction	Alkaline				Acid							
Plant comm. type	*A. lanata*	*Carex nigricans*	*V. scoparium*	*Phyllodoce glanduliflora*	*Cassiope*					*V. scoparium*	*S. arctica A. lanata*	*Salix arctica*
Mass-wasting		+[4]		+	+	+	+	++	+	+	+	
Snow release	Moderately early											
Comments	Lithic		Lithic						Lithic			

1 Letters indicate compass direction
2 Drainage classes D1 = rapidly drained; D- = well drained; D3 = moderately well drained; D4 = imperfectly drained; D5 = poorly drained; D6 = very poorly drained.
3 Parent materials A = aeolian; Av = alluvium; C = colluvium; T = till; BR = bedrock
4 + indicates disturbance; ++ indicates severe disruption

from non-calcareous shales and conglomerates. Aeolian materials are also present in the sola of these soils.

Alpine Dystric Brunisols are common in the undulating to rolling alpine divide area where snow release occurs in approximately mid-July. The soil at T9 was selected as being representative of the Alpine Dystric Brunisols of this area.

The well-drained pedon at T9 (Plate 4) has developed from aeolian and till parent materials with bedrock being close to the surface. The plot is located east of Rock Isle Lake on an 8% southwest-facing slope at 2330 m (7700 feet) above sea level. Vegetation consists of an *Antennaria lanata* community type.

Horizon	Depth (cm)	
L	3-0	Dark gray (10YR 4/1 d) fibrous turf; abundant; fine random roots; very strongly acid; clear, wavy boundary; 2 to 6 cm thick.
Ah	0-1	Dark brown (10YR 3/3 m) silt loam.
Bm	1-6	Strong brown (7.5YR 5/6 m), yellowish brown (10YR 5/4 d) silt loam; weak, fine granular; very friable; abundant; fine random roots; medium acid; clear, wavy boundary; 3 to 10 cm thick.
C	6-7	Light yellowish brown (10YR 6/4 d) gravelly sandy loam; moderate, fine granular; friable; few, fine vertical roots; 50% coarse fragments; gradual, broken boundary; 0 to 2 cm thick.

Horizon	Depth (cm)	
IIBC	7-40	Very dark grayish brown (10YR 3/2 m), grayish brown (10YR 5/2 d) gravelly loam; moderate, medium granular; friable; plentiful, fine random roots; weakly effervescent; mildly alkaline; abrupt, wavy boundary; 20 to 40 cm thick.
R	40+	Bedrock.

These soils are usually rapidly drained but well, moderately well, and imperfectly drained variants are present (Table 2). There is no visual evidence of pedogenic translocations within the profiles.

The Alpine Dystric Brunisol at T11 (Plate 5) shows evidence of active soil creep that is common when these soils occur on steep slopes and at high elevations. This is a rapidly-drained soil developed on non-calcareous parent materials at an elevation of 2345 m (7700 feet) on the east slope of Wa-Wa Ridge under a *Phyllodoce glanduliflora* community type.

Horizon	Depth (cm)	
L	1-0	Turf.
Ah1	0-8	Very dark grayish brown (10YR 3/2 m), dark grayish brown (10YR 4/2 d) shaley sandy loam; weak, fine granular; very friable; plentiful, fine random roots; 50% coarse fragments; very strongly acid; clear, wavy boundary; 5 to 12 cm thick.

Alpine Dystric Brunisol (T9)

The knife (25 cm) is resting on bedrock.

Alpine Dystric Brunisol (T36)

Large amounts of aeolian material are present in surface horizons.

Alpine Eutric Brunisol II (T4)

The shallow profile has a brightly colored B horizon (knife = 20 cm)

PLATE 4. Profile characteristics of Alpine Dystric and Eutric Brunisols

Plot T11 is located on the flank of Wa-Wa Ridge at 7700'. Plant cover includes *Phyllodoce glanduliflora*, *Antennaria lanata*, and islands of *Larix lyallii*.

The soil profile (Alpine Dystric Brunisol) has a thick Ah horizon and a discontinuous B horizon due to the effects of soil creep.

PLATE 5. Site and soil profile at plot T11

Horizon	Depth (cm)	
Ah2	8-15	Very dark grayish brown (10YR 3/2 m), grayish brown (10YR 5/2 d) sandy loam; weak, fine granular; very friable; few, fine random roots; 10% coarse fragments, strongly acid; abrupt, wavy boundary; 3 to 10 cm thick.
Bm1	15-18	Dark brown (7.5YR 4/4 m) silt loam; weak, fine granular; friable; very few, fine random roots; abrupt, wavy boundary; 0 to 5 cm thick.
IIBm	18-26	Dark yellowish brown (10YR 4/4 m), pale brown (10YR 6/3 d) silt loam; moderate, medium subangular blocky; friable; very few, fine random roots; 10% coarse fragments; strongly acid; clear, wavy boundary; 7 to 12 cm thick.
IIBC	26-34	Dark grayish brown (2.5Y 4/2 m) clay loam; moderate, medium subangular blocky; friable; no roots; 15% coarse fragments; gradual, wavy boundary; 2 to 10 cm thick.
IIC	34-70+	Dark grayish brown (2.5Y 4/2 m), light brownish gray (2.5Y 6/2 d) silt loam; fragmental; firm; strongly acid.

Alpine Dystric Brunisols are associated with several plant community types, especially *Phyllodoce glanduliflora*, *Cassiope tetragona*, *Cassiope mertensiana*, *Vaccinium scoparium*, and *Antennaria lanata* community types.

A Degraded Alpine Dystric Brunisol (L1) located at the upper fringe

of the forest tundra ecotone on the east slope of Wa-Wa Ridge was the only soil examined in the area that showed evidence of eluviation. This soil was developed on a 15% slope under a mixed community of *Phyllodoce glanduliflora*, *Vaccinium scoparium* and *Antennaria lanata* with scattered individuals of *Larix lyallii* displaying krummholz form. The profile description of this soil follows.

Horizon	Depth (cm)	
L	2-0	Very dark grayish brown (10YR 3/2 d) densely rooted turf; abundant, fine and medium horizontal roots; and abundant, fine vertical roots; less than 5% coarse fragments; clear, wavy boundary.
Ah	0-5	Dark brown (10YR 3/3 m), dark grayish brown (10YR 4/2 d) loam; moderate, fine granular; friable; abundant, fine random roots; very strongly acid; clear, wavy boundary; 3 to 6 cm thick.
Ahe	5-9	Brown (10YR 4/3 m, 5/3 d) loam; weak, fine granular; very friable; plentiful, fine random roots; less than 5% coarse fragments; very strongly acid; gradual, wavy boundary; 3 to 5 cm thick.
Bm	9-17	Dark brown (7.5YR 4/4 m), yellowish brown (10YR 5/6 d) silt loam; moderate, fine granular; friable; plentiful, fine random roots; less than 5% coarse fragments; strongly acid; clear,

Horizon	Depth (cm)	
Bm (con't)		wavy boundary; 5 to 10 cm thick.
IIBC	17-24	Yellowish brown (10YR 5/4 m), light yellowish brown (10YR 6/4 d) loam; moderate, medium fine granular; friable; very few, fine random roots; 10% coarse fragments; strongly acid; gradual, smooth boundary; 5 to 12 cm thick.
IIC	24-56+	Olive brown (2.5Y 4/4 m), light yellowish gray (10YR 6/2 d) loam; fragmental; firm, very few, fine random roots; 15% coarse fragments; strongly acid.

This soil may have been under coniferous vegetation at some time in the recent past which could account for the presence of an Ahe horizon.

Alpine Eutric Brunisols - Alpine Eutric Brunisols were described and sampled in 16 locations (Table 3). These soils occupy various positions in the landscape and display a wide range in characteristics. A general horizon sequence is L, Ah(k), Bm(k), C(k), (R) with three principal variants recognized.

TYPE I. Alpine Eutric Brunisols in the rolling alpine divide area have essentially the same occurrence, sequence and depths of horizons and similar textures, structure and consistence as the Alpine Dystric Brunisols. Separation of these soils was made on the basis of reaction and base saturation of the Bm horizons. The soil at plot T3, which is adjacent to T9 described above, is representative of this type of

Table 3 SITE CHARACTERISTICS OF THE ALPINE EUTRIC BRUNISOLS

	Type I	Type II					Type III			Others						
Plot	T3	T4	T18	T28	T1	T19	T32	T52	T55	T20	T40	T47	T5	T10	T14	T37
Elev m	2330	2410	2485	2400	2420	2470	2270	2400	2530	2280	2200	2260	2380	2250	2315	2265
ft	7700	7900	8150	7860	7935	8100	7450	7865	8300	7475	7200	7420	7800	7380	7600	7430
Slope %	-	10	20	15	30	35-40	20	12	50	25	55-60	-	35	7	1-3	-
Aspect	W[1]	W	WSW	W	W	SSW	S	S	SE	NE	N	E	W	E	SW	-
Drainage	D1[2]	D1	D1	D1	D1	D1	D1	D2	D1	D1	D1	D1	D1	D5	D5	D4
P.M.	T+A[3]	C	C+A/BR	C/T	C/BR	C+A/BR	T/BR	C/BR	C+A	C	C	C/BR	A+T/BR	Av	Av	A+T
P.M. reaction	Alk	Acid	Alkaline													
Plant comm. type	*P.glanduliflora*	*Dryas hookeriana*		*Dryas hookeriana Carex scirpoidea*			*Kobresia myosuroides*			*Saxifraga lyallii*			*C.mertensiana*	*Salix barrattiana*		*Salix arctica*
Mass-wasting	+[4]	+	+	+	+	+	+	+	+	+	+	+	+			+
Snow release	Mod.	Early	Early	Early	Early	Early	Early	Early	Early	Late	Late	Late	Early	Mod.	Mod.	Mod.
Comments			Lithic			Lithic	Lithic	Lithic				Lithic	Lithic			

1 Letters indicate compass direction
2 Drainage class D1 = rapidly drained; D2 = well drained; D4 = imperfectly drained; D5 = poorly drained
3 Parent material A = aeolian; Av = alluvium; C = colluvium; T = till; BR = bedrock
4 + = disturbance

Alpine Eutric Brunisol. This is a rapidly-drained soil located at an elevation of 2330 m (7700 feet) on a gentle west-facing slope east of Rock Isle Lake under a *Phyllodoce glanduliflora* community type. The profile description of this soil follows.

Horizon	Depth (cm)	
L	3-0	Very dark gray to black (10YR 2.5/1 d) fibrous turf; abundant, fine random and abundant, medium horizontal roots; strongly acid; abrupt, smooth boundary.
Ah	0-5	Very dark grayish brown (10YR 3/2 m), very dark gray (10YR 3/1 d) silt loam; weak, fine granular; very friable; plentiful, fine vertical roots; 15% coarse fragments; medium acid; clear, wavy boundary; 1 to 8 cm thick.
Bm	5-13	Dark brown (7.5YR 4/4 m, 10YR 4/3 d) silt loam; weak, medium granular; very friable; few, fine vertical roots; 15% coarse fragments; neutral; clear, wavy boundary; 4 to 15 cm thick.
IIBC	13-30	Yellowish brown (10YR 5/6 m, 5/4 d) gravelly silt loam; moderate, fine granular; friable, very few, fine vertical roots; 40% cobbles; mildly alkaline; 10 to 20 cm thick.
IIICk	30-70+	Dark brown (10YR 4/3 m), grayish brown (10YR 5/1 d) very gravelly sandy loam; very few, fine vertical roots to 40 cm; 70% coarse fragments; mildly alkaline.

The Ah and Bm horizons have considerable aeolian content mixed with the till and have been moved and mixed by mass wasting and ground squirrel activity. The IIBC is till that has been moved or loosened by roots; and the IICk is more compact till that has not been disturbed.

TYPE II. Alpine Eutric Brunisols located on steep westerly-facing slopes at high elevations (T1, T4, T18, T19, and T28) have distinct characteristics (Plate 4). Due to exposure to the prevailing winds these soils have light snow cover and experience early snow release and moisture stress during the summer. Vegetation at T4, T18, and T28 consists of *Dryas hookeriana* community type and at T1 and T19 of a *Dryas hookeriana* - *Carex scirpoidea* type. All of these soils, except at T4, are calcareous in the B and C horizons and often in the A horizons. Profile development is weak and these soils are associated with Regosols. Large amounts of scree are present on the surface of these soils and bedrock often occurs within 50 cm. Lenses of aeolian materials are occasionally found in the surface horizons.

TYPE III. The soils at sites T32, T52, and T55 were also classified as Alpine Eutric Brunisols. These soils occur on wind-exposed south-facing slopes under *Kobresia myosuroides* community types where snow cover is light to absent. The following profile description of a rapidly-drained soil at site T55 on Quartz Hill at 2510 m (8300 feet) is typical of those soils under *Kobresia*.

Horizon	Depth (cm)	
L	4-0	Fibrous turf; abundant, fine random roots; gradual, wavy boundary; 2 to 7 cm thick.

Horizon	Depth (cm)	
Ahk	0-15	Black (10YR 2/1 m), very dark gray (10YR 3/1 d) loam; moderate, medium granular; very friable; abundant, fine vertical roots; very weakly effervescent; 5% coarse fragments; neutral; gradual, wavy boundary; 10 to 20 cm thick.
Bmk	15-18	Yellowish brown (10YR 5/6 m) silt loam; weak, fine granular; very friable; plentiful, fine vertical roots; very weakly effervescent; 10 to 15% coarse fragments; mildly alkaline; abrupt, broken boundary; 0 to 5 cm thick.
IIC	18-50+	Dark grayish brown (10YR 4/2 m), grayish brown (10YR 5/2 d) very gravelly sandy loam; few, fine vertical roots to 40 cm; weakly effervescent; 80% coarse fragments; mildly alkaline.

The Ah horizons under the densely-rooted *Kobresia* turfs are some of the deepest and darkest colored found in the area. Bulk density of these Ah horizons is low (0.5 to 1.0 g cm^{-3}). The C horizons are sandier and have higher coarse fragment content than the A or B horizons. Soils in three late snowbed areas (Plots T20, T40, and T47) under *Saxifraga lyallii* communities are examples. The turfs are not continuous and are not as densely rooted under the discontinuous *Saxifraga* cover as under other community types. Solum thickness varies from 0 cm where large boulders protrude from the colluvium or where recent mass-wasting has caused profile disruption, to 40 cm in more stable areas. The

combination of churning and mixing by mass-wasting and weak horizon development makes horizons difficult to separate. At plots T10 and T14 Alpine Eutric Brunisols have developed on alluvial deposits under *Salix barrattiana* communities. The plots are located on slightly raised landscape positions that are presently above the level of stream flow but are poorly drained. An imperfectly drained Alpine Eutric Brunisol was observed at T37 under *Salix arctica* community type.

Orthic Regosols - Orthic Regosols of two main types were found associated with Alpine Eutric Brunisols in late snowbed locations and on high windswept slopes (Table 4). These are mineral soils with an L, Ah(k), C(k), (R) horizon sequence that are freely drained. They occur on calcareous and non-calcareous parent materials.

TYPE I. Orthic Regosols that have thin, discontinuous Ah horizons occur in late snowbed areas. Snowmelt occurs in August although small patches of snow may not melt in some years. The Orthic Regosol at T33, in a snowbed location on the east side of Quartz Hill is an example (Table 4 and Appendix).

TYPE II. Orthic Regosols with deep, dark-colored Ah horizons are common at high elevations on steep, wind-exposed slopes. The rapidly-drained Orthic Regosol at T7 (Plate 6) on an 11% southwest-facing slope of Lookout Mountain at 2540 m (8400 feet) is representative of many of the Type II Orthic Regosols that occur on the high, wind-desiccated slopes under *Dryas hookeriana* and *Dryas hookeriana - Carex scirpoidea* community types. The profile description of this soil follows.

Table 4 SITE CHARACTERISTICS OF ORTHIC REGOSOLS

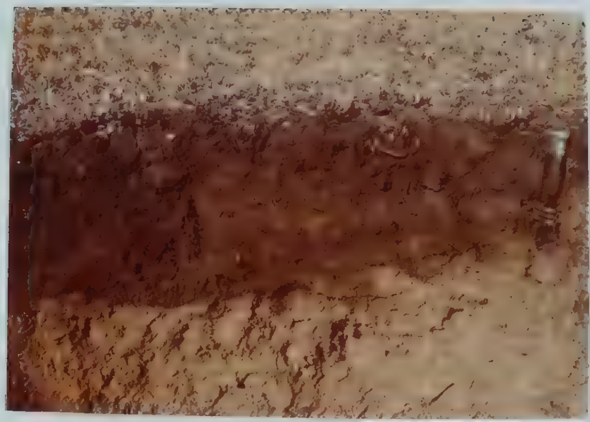
	Type I	Type II		Other
Plot	T33	T6	T7	T54
Elev. m	2340	2415	2560	2400
ft	7670	7950	8400	7860
Slope %	60	30	11	10-15
Aspect	E[1]	W	SW	S
Drainage	D1[2]	D1	D1	D1
P.M.	C[3]	C/BR	C/BR	A+C/T
P.M. reaction	alkaline			
Plant comm. type	*Saxifraga lyallii*	*Dryas hookeriana*	*Dryas hookeriana Carex scirpoidea*	*Cassiope tetragona*
Mass-wasting	++[4]	+	+	+
Snow release	late	early	early	early

1 Letters indicate compass directions
2 Drainage class, D1 = rapidly drained
3 Parent materials, A = aeolian, C = colluvium,
T = till, BR = bedrock
4 + indicates disturbance, ++ indicates severe disruption

Horizon	Depth (cm)	
L	2-0	Dryas turf; plentiful, fine vertical and abundant, medium horizontal roots; clear, smooth boundary; 1 to 3 cm thick.
Ahk1	0-5	Very dark gray (10YR 3/1 m, 3/1.5 d) gravelly silt loam; weak, fine granular; very friable; plentiful, fine random roots; moderately effervescent; 50% coarse fragments; mildly alkaline; clear, broken boundary; 0 to 15 cm thick.
Ahk2	5-15	Dark brown (10YR 3/2 m), dark grayish brown (10YR 4/2 d) silt loam; weak, fine granular; very friable; few, fine vertical roots; moderately effervescent; 15% coarse fragments; mildly alkaline; abrupt, wavy boundary; 5 to 15 cm thick.
IICk	15-60	Brown (10YR 5/3 m), light brownish gray (10YR 5.5/2 d) very gravelly sandy loam; single grained; loose; few, fine vertical roots to 40 cm; strongly effervescent; mildly alkaline; abrupt, irregular boundary.
R	60+	Bedrock.

These soils are severely disrupted by soil creep and frost action and vary considerably as to depth of horizons and depth to bedrock with local slope.

The Orthic Regosol at T54, under *Cassiope tetragona* community type



The Orthic Regosol II at T7 occurs at 8400' under a mixed *Dryas* - *Carex* community type. (knife handle = 10 cm).

The Rego Humic Gleysol at T27 is typical of soils in poorly drained areas.

PLATE 6. Orthic Regosol and Rego Humic Gleysol profiles

has a deep, black Ah similar to those Alpine Eutric Brunisols under *Cassiope* and *Kobresia*, but active soil creep processes have inhibited the development of a B horizon.

Cumulic Regosols - Two types of Cumulic Regosols were recognized in the area.

TYPE I. Soils developed on recent alluvial deposits in runoff channels or basins where periodic deposition of sediments buries previously-developed Regosolic profiles have Ah, C, Ah, C ... profiles in which organic matter content decreases irregularly with depth (Plate 7). These soils are classified as Type I Cumulic Regosols.

These soils were described and sampled in six locations (Table 5). *Salix barrattiana* community type occurs at four of these locations with *Salix arctica* and *Carex nigricans* community types at the other two sites. Soil textures are usually silt loam throughout the profile and the soils are often poorly drained.

TYPE II. Soils developed on steep slopes, generally north-to-east facing, where very active soil movement results in a series of truncated and buried soil profiles were classified as Type II Cumulic Regosols (Plate 7). These soils experience late snow release and moist conditions late in the summer. There is often limited groundwater seepage on the slopes. These soils were described and sampled at 3 locations (Table 5). Plant cover at these sites consists of *Anemone occidentalis* community type.

Soil profiles are severly disturbed with deeply churned AC horizons often being evident. Rocks beneath or partly beneath the soil surface turn while moving downslope causing folding and mixing

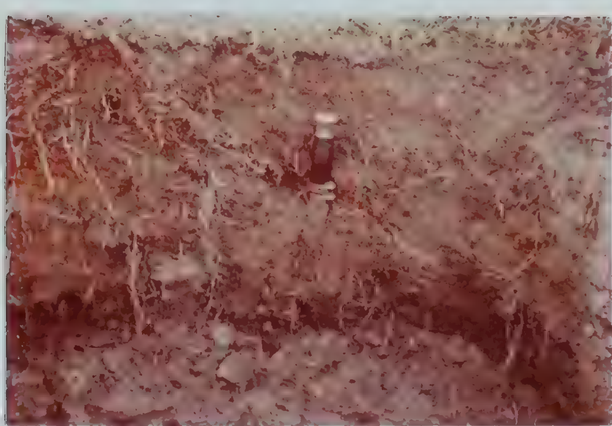
Table 5

SITE CHARACTERISTICS OF THE CUMULIC REGOSOLS

	Type I						Type II			
Plot	T12	T22	T34	T35	T31	T41	T21	T29	T44	T39
Elev m	2260	2240	2235	2265	2360	2310	2220	2240	2265	2170
ft	7400	7360	7340	7430	7740	7580	7275	7350	7440	7140
Slope	1	-	2	0-1	10	15	65	40-60	27	50
Aspect	-[1]	-	-	-	SW	E	E	NE	SE	N
Drainage	D5[2]	D5	D5	D5	D2	D3	D1	D1	D1	D1
P.M.	Av[3]	Av	Av	Av	Av	Av+C / BR	C	C	C	C
P.M. reaction	Acid	Alkaline				Acid	Alk.	Alk.	Acid	Alk.
Plant comm. type	*Salix barrattiana*				*Salix arctica*	*Carex nigricans*	*Anemone occidentalis*			
Mass-wasting						+[4]	++	++	++	++
Snow release	Moderately early						late	late	late	late

1 Letters indicate compass directions
2 Drainage class D1 = rapidly drained; D2 = well drained; D3 = moderately well drained; D5 = poorly drained.
3 Parent materials Av = alluvium; C = colluvium; BR = bedrock
4 + indicates disturbance; ++ indicates severe disruption

Cumulic Regosol (I) commonly occurs on alluvial deposits under *Salix barrattiana* (knife handle = 10 cm).



Cumulic Regosol (II) occurs on steep, active slopes under *Anemone occidentalis*.

PLATE 7. Cumulic Regosol soils

of horizons.

<u>Gleysols</u> - Gleysolic soils were observed in areas of groundwater discharge and ponded runoff (Table 6). The soils are saturated with water throughout the year, have matrix colors of low chroma, and are mottled in some horizons (Plate 6). The Bg and occasionally the Ahg horizons lack structural development. Textures are generally silt loam throughout the profile.

An Orthic Gleysol occurs at Plot T46 under *Carex eleusinoides* community type and Orthic Humic Gleysols (with an Ah > 8 cm thick) were described and sampled at T26, T43, and T45. *Eriophorum scheuchzeri* communities are present at T26 and T45 and an *Eriophorum angustifolium* community type at T43. Surface relief of the soil at T43 is hummocky, with as much as 30 cm relief. A peat accumulation of up to 10 cm in thickness is present.

Rego Humic Gleysols, which have no B horizons, occur at several locations (T2, T27, T38, and T48). The profile description of the Rego Humic Gleysol at T27 under an *Eriophorum angustifolium* community in a groundwater discharge area east of Wa-Wa Ridge illustrates the low chroma colors and profile morphology of the Gleysolic soils in the area.

Horizon	Depth (cm)	
Ahg	0-10	Very dark gray (5Y 3/1 m), light olive brown (2.5Y 5/4 d) gravelly sandy loam; weak, medium, granular; slightly sticky; plentiful, fine random roots; 15% coarse fragments; slightly acid; abrupt, wavy boundary; 8 to 12 cm thick.

Table 6 SITE CHARACTERISTICS OF THE GLEYSOLIC SOILS

Plot	T27	T38	T48	T2	T46	T26	T45	T43
Elev. m	2350	2265	2280	2440	2280	2380	2270	2320
ft	7700	7430	7480	8000	7480	7800	7450	7610
Slope %	-	1	0-1	-	0-1	0-1	-	-
Aspect	-	-	-	-	-	-	-	-
Drainage	D6[1]	D5	D5	D5	D6	D5	D6	D6
P.M.	C[2]	T	Av	C	Av	Av	Av	Av
P.M. reaction	Acid	——— Alkaline ———			——— Alkaline ———			
Plant comm. type	*Eriophorum angustifolium*	*Carex saxitilis*	*Carex sp.*	*Salix nivalis*	*Carex eleusinoides*	*Eriophorum scheuchzeri*	*Eriophorum scheuchzeri*	*Eriophorum angustifolim*
Comments	Rego Humic Gleysol	Rego Humic Gleysol	Rego Humic Gleysol	Rego Humic Gleysol	Orthic Gleysol	Orthic Humic Gleysol	Orthic Humic Gleysol	Orthic Humic Gleysol

1 Drainage class D5 = poorly drained; D6 = very poorly drained
2 Parent materials Av = alluvium (including alluvial-lacustrine); T = till; C = colluvium

Horizon	Depth (cm)	
Cg1	10-35	Gray (N5 m) light gray (5Y 6/1 d) silt loam; common, fine distinct olive (5Y 4/4 m) mottles; amorphous; firm; very few, fine random roots; medium acid; diffuse, smooth boundary.
Cg2	35-55	Gray (N5 m), olive (5Y 5/3 d) silt loam; many, coarse, prominent brown (10YR 4/3 m) mottles; amorphous; firm; 5% coarse fragments; neutral; diffuse, smooth boundary.
Cg3	55+	Gray (N5 m) silt loam; amorphous; firm.

Earth Hummocks - Patterned ground features classified as earth hummocks (Washburn, 1956) are present in several locations within the study area. Cross sections of the hummocks were examined at plots T23, T24, T25, and T51 (Table 7). At each location the hummocks occupy a small enclosed depression (ca. 30 m diameter) in the landscape (Plate 8). The hummocks are developed on deposits of Mazama ash of up to 1 m in thickness. The ash is underlain by a thin lacustrine deposit suggesting the ash was deposited in a pond which might account for the unusual thickness of the deposit. The hummocks are approximately 75 cm in diameter and have 20 to 40 cm relief. *Carex nigricans* uniformly covers the hummocky pattern providing a continuous, densely-rooted turf. Plate 8 and the following profile description of the hummocks at T24 illustrates the profile morphology of these soils.

Earth hummocks in the basin at right center (T24) experience fairly late snow release, as evidenced by the yellow cover of *Carex nigricans*. Aug. 9, 1972.

Surface morphology of the earth hummocks. Aug. 19, 1970.

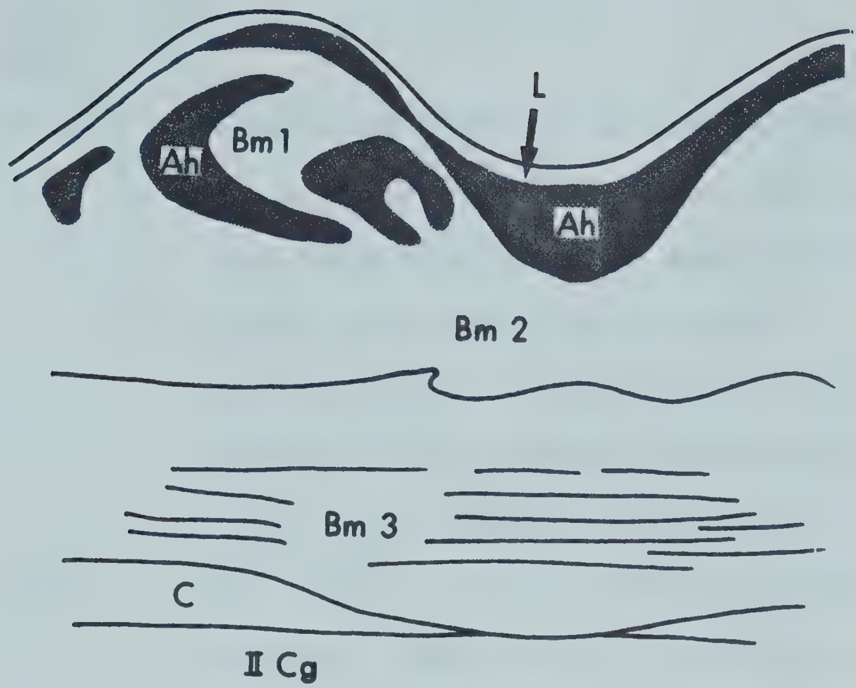
Soil profile under the earth hummocks. (knife = 25 cm).

PLATE 8. Photographs of the Earth Hummocks

Table 7 SITE CHARACTERISTICS OF THE EARTH HUMMOCKS

Plot	T23	T24	T25	T51
Elev. m	2250	2290	2290	2310
ft	7400	7500	7500	7560
Slope %	-	-	-	0-1
Aspect	-	-	-	-
Drainage	D4	D4	D4	D4
P.M.	Ash	Ash	Ash	Ash
P.M. reaction	Acid	Acid	Acid	Acid
Plant comm. type	*Carex nigricans*	*Carex nigricans*	*Carex nigricans*	*Carex nigricans*

1 Drainage class D4 = imperfectly drained



Profile Sketch (1/10 scale)

Horizon	Depth (cm)	
L	3-0	Fibrous turf; abundant, fine random and abundant, medium horizontal roots; clear, wavy boundary.
Ah	0-9	Black (10YR 2/1 m), dark grayish brown (10YR 4/2 d) silt loam; weak, fine granular; very friable; abundant, fine vertical roots; strongly acid; irregular boundary.
Ah + Bm1	1-26 under hummock	Strong brown (7.5YR 5/6 m) silt loam; weak, medium granular; friable; plentiful, fine random roots; medium acid; clear, broken boundary.
Bm2	9-19	Yellowish brown (10YR 5/6 m) silt; weak, medium platy; very friable; plentiful, fine vertical roots; slightly acid; gradual, wavy boundary.

Horizon	Depth (cm)	
Bm3	19-49	Strong brown (7.5YR 5/6 m) interband and yellowish red (5YR 4/6 m) bands, silt; strong, fine platy; firm; few, fine vertical roots; slightly acid; clear, wavy boundary.
C	49-53	Light yellowish brown (10YR 6/4 m) silt; amorphous; firm; very few, fine vertical roots; slightly acid; abrupt, smooth boundary.
IICg1	53-57	Dark grayish brown (2.5Y 4/2 m) silty clay loam; amorphous; firm; very few, fine vertical roots; gradual, smooth boundary.
IICg2	57-77+	Light olive brown (2.5Y 5/4 m) silty clay loam; amorphous; firm; roots to 75 cm; medium acid.

Summary of Field Investigations

Significant relationships were noticed between soils, plant community types, and environmental parameters which are summarized in Table 8. Attempts at comparing characteristics of plant and soil distribution patterns must be done using comparable levels of abstraction in the classification scheme of each. In this discussion, plant community type is compared to soil subgroup in the case of the Alpine Dystric Brunisols and the Gleysolic soils and to subdivisions of other subgroups. These subdivisions are approximately equivalent to a soil series level of classification.

Alpine Dystric Brunisols and the morphologically similar Type I Alpine Eutric Brunisols are the most common soils in the undulating to rolling alpine divide area and are commonly associated with *Phyllodoce glanduliflora* and *Antennaria lanata* community types. These are turfy alpine soils with dark Ah horizons and high amounts of amorphous colloids in their A and B horizons.

Cassiope tetragona community types are often associated with Alpine Dystric Brunisols on fairly exposed slopes and ridges.

In the late snowbed areas on lee slopes Type I Orthic Regosols and weakly developed Alpine Eutric Brunisols with discontinuous Ah horizons occur under sparse communities of *Saxifraga lyallii*.

On the steep, west-facing slopes at elevations generally greater than 2380 m (7800 feet) *Dryas hookeriana* and *Dryas hookeriana* - *Carex scirpoidea* community types occur, often in striped patterns, on Type II Orthic Regosols and Type II Alpine Eutric Brunisols, both of which have deep Ah horizons. These soils may be calcareous to the

Table 8 SOIL CLASSIFICATION, PLANT COMMUNITY TYPE AND

SITE CHARACTERISTICS OF THE SAMPLE PLOTS

Plant Community Type	Soil Classification								
	Alpine Dystric Brunisol	Alpine Eutric Brunisols				Orthic Regosols		Cumulic Regosols	
		I	II	III	Other	I	II	I	II
Dryas hookeriana *Carex scirpoidea*			1, 19 4, 18 28				6, 7		
Saxifraga lyallii					20,40 47	33			
Kobresia myosuroides				32,52 55					
Cassiope spp.	11,13,15 16,49				5		(54)		
Phyllodoce glanduliflora	30	3							
Antennaria lanata	9,42								
Vaccinium scoparium	8,50								
Salix arctica	36,42				37			31	
Salix nivalis									
Salix barrattiana					10,14			12,22 34,35	
Anemone occidentalis									21,29 39,44
Carex nigricans									
Eriophorum spp.									
Carex spp.									

The numbers indicate plot numbers with the "T" designation omitted.

Gleysols Rego	Gleysols Orth	Gleysols Hum.	Earth Hum-mocks	Elevation 7500	Elevation 7500 -8000	Elevation 8000	Slope 0-10%	Slope 10-25%	Slope 25-40%	Slope >40%
					1, 4 16,28	7,18 19	4	7,18 28	1,6 19	
				20,40 47	33				20	33,40
				32	52	55		32,52		55
					11,13 54,15 16,49 5			11,13 15,16 49,54	5	
					3,30				30	
					9,42		9	42		
					8,50			8	50	
				36,37	31		31,36			
2						2	2			
				10,12 22,34 35	14		10,12 14,22 34,35			
				21,29 39,44					44	21,29 39
			23,24 25,51	23	17,24 25,41 51		17,23 24,25 51	41		
27		26,43 45		45	26,27 43		26,27 43,45			
38, 48	46			38,46 48			38,46 48			

surface and are severely disrupted by soil creep.

Kobresia myosuroides communities were found on high, southerly exposed slopes in association with Type III Alpine Eutric Brunisols which have deep, black Ah horizons and Bm horizons of high chroma.

Type I Cumulic Regosols have developed on alluvial deposits in drainage channels under *Salix barrattiana* community type. Type II Cumulic Regosols are present on steep north-to east-facing slopes where mass-wasting is very active under *Anemone occidentalis* community type. Both types show sequences of buried horizons.

Carex eleusinoides, *Eriophorum scheuchzeri*, and *Eriophorum angustifolium* community types occur in poorly drained depressional areas where the soils are saturated with water most of the year. Where plant cover is discontinuous or sparse Orthic and Rego Humic Gleysols occur but some of the wet soils have more continuous plant cover, have deep Ahg horizons, and are classified as Humic Gleysols.

The earth hummock patterns have developed on thick accumulations of volcanic ash under continuous cover of *Carex nigricans* community type. The highly turbated soils cannot be classified using the present Canadian system.

PART IV. LABORATORY INVESTIGATIONS OF THE SOILS

Methods

Soil samples collected in the field were air dried and crushed in a steel roller mill. The material passing through a 2 mm sieve was stored in glass containers for laboratory analyses.

Physical Analyses

Particle size distribution - The hydrometer method of Day (1965) was used. Organic matter was removed using 35% hydrogen peroxide. Carbonates were not destroyed. Sand fractions were determined by sieve analysis.

Specific gravity separations - The fine sand fractions (0.25 - 0.10 mm) were divided into four fractions using bromoform - benzene (s.g. 2.50), bromoform - benzene (s.g. 2.75) and tetrabromoethane (s.g. 2.94).

Bulk density - A small hand coring device was used to take volume samples in the field. These were stored in plastic bags and oven dried and weighed.

Particle density - An air comparison pycnometer was used to obtain mean particle density of the <2 mm soil fraction.

Soil Moisture Analyses

Air-dry moisture percentage - Air-dry moisture content was determined by oven drying samples overnight at 105°C.

15 bars moisture percentage - Moisture content at 15 bars tension was determined by the method of Richards (U.S. Salinity Laboratory Staff, 1954) using a cellulose membrane in a pressure membrane apparatus.

1/10 bars moisture percentage - Moisture content at 1/10 bars tension was determined by the method of Richards (U.S. Salinity Laboratory Staff, 1954) using a pressure plate apparatus.

Chemical Analyses

Soil reaction - pH values were determined by two methods; (i) the saturated soil paste method of Doughty (1941), and (ii) a 2:1 solution: soil ratio using 0.01 M $CaCl_2$ (Peech, 1965). In both cases a Beckman model zeromatic pH meter with glass and calomel electrodes was used for measurement.

Total nitrogen - The Kjeldahl-Wilfarth-Gunning method (A.O.A.C., 1955) was used for the determination of total nitrogen. The catalyst used was HgO (0.41 g), $CuSO_4$ (0.08 g), and K_2SO_4 (9.9 g) packaged in a polyethylene bag and sold commercially as Kel-pak. The ammonia was collected in a 4% H_3BO_4 solution as suggested by Meeker and Wagner (1933) and titrated against standardized H_2SO_4.

Organic carbon - A modification of Walkely's wet oxidation method (U.S. Salinity Laboratory Staff, 1954) was used to determine organic carbon content. Percent organic carbon was multiplied by the Van Bemmelen factor of 1.72 (Waksman, 1938) to give percent organic matter.

Calcium carbonate equivalent - A Smolik calcimeter (Bascomb, 1961) was used to estimate calcium carbonate equivalent based on the increase in volume of a closed system due to release of CO_2 when HCl is added to a soil sample. The CO_2 evolved was converted to $CaCO_3$ equivalent. This analysis was performed on soil samples with a pH (water) of 7.0 or greater. Soils with pH less than 7.0 are not expected to contain

appreciable amounts of carbonates. $MgCO_3$ and $CaMg(CO_3)_2$ may contribute to the $CaCO_3$ equivalent data.

Exchangeable cations and total exchange capacity - Exchangeable cations were extracted with 1N ammonium acetate buffered to pH 7.0 as outlined in A.O.A.C. (1955). Exchangeable calcium, magnesium, potassium, and sodium were determined with a Perkin-Elmer model 303 Atomic Absorption Spectrophotometer. Total exchange capacity (TEC) was determined by extraction of adsorbed ammonium ions with 1N sodium chloride and distillation of the extract as outlined in A.O.A.C. (1955).

Exchangeable acidity - Exchangeable acidity was determined by leaching the soil with 0.5N barium acetate. The leachate was titrated with standardized sodium hydroxide as suggested by Brown (1943).

Oxalate-extractable aluminum and iron - The oxalate extraction method of McKeague and Day (1966) was used for extraction of amorphous aluminum and iron. Aluminum was determined colorimetrically with Aluminon and iron by atomic absorption spectrophotometry.

Pyrophosphate-extractable aluminum and iron - A 0.1M pyrophosphate extraction (McKeague, 1967) was used to extract organically-complexed aluminum and iron. Aluminum and iron were determined by atomic absorption spectrophotometry.

Phosphorus - An estimation of available phosphorus was made using the sodium bicarbonate extraction method of Olsen *et al.*,(1954). Phosphorus was determined colorimetrically with the ascorbic acid-reduced molybdo-phosphoric blue color method of Alexander and Robertson (1970).

Clay Mineralogy Investigations

Clay separations - Clay-size particles were separated using centrifugation after sample pretreatments with 35% hydrogen peroxide, sodium acetate (pH 5.0), and citrate-dithionite (Kittrick and Hope, 1963).

X-ray diffraction analysis - Mg- and K-saturated total clay fractions ($<$2u) were oriented on glass slides (Jackson, 1956). The clays received the following treatments:

(i) Mg saturation, air dried, (ii) Mg saturation, glycolated, (iii) K saturation, air dried, (iv) K saturation, heated to 350°C for 4 hours, (v) K saturation, heated to 550°C for 4 hours. A Philips x-ray diffractometer using nickel-filtered CuKα radiation was used to obtain diffraction patterns.

Amorphous clay-size material - A quantitative estimate of amorphous aluminosilicates in the total clay fraction was made using the NaOH dissolution procedure of Hashimoto and Jackson (1960). Aluminum was determined with Aluminon (Hsu, 1963) and silica by the molybdate method (Kilmer, 1965).

Results and Discussion

Particle Size Distribution

Particle size analysis was done on an organic matter-free basis but carbonates were not removed as pretreatment with HCl was found to drastically alter particle size distribution of those soils developed on calcareous parent materials (Knapik, unpublished)[1]. The presence

1 Soil Science 531 project report, April, 1971

of carbonates did not prevent good dispersion with sodium hexametaphosphate.

Particle size distribution results for the 8 selected profiles are shown in Table 9. The Ah and Bm horizons are typically silt loam in texture while the IIC horizons, with 10 to 40% less silt, are typically loam to sandy loam in texture. Clay content is low (2 to 20%) throughout the profile. Cumulative particle size distribution curves of the Ah, Bm, and IICk horizons of Alpine Eutric Brunisol T3 are shown in Figure 5. These curves illustrate the change in silt content from the Ah and Bm horizons to the IICk horizon. Median particle size diameter (50% cumulative percentage) of the solum samples is in the coarse silt fraction whereas for the IICk sample median particle size is very fine sand. These curves can be compared to those of the ash samples from the earth hummocks in Figure 6. The curves representing the predominately ash Ah and C horizons are almost entirely within the silt size class and show a median particle size of approximately 20μ.

Sand Fractions

Particle size distribution of the sand fractions from the selected profiles are given in Table 9 as percentage of total sand. The very fine sand content decreases sharply at the boundary between the I and II materials which reflects the distribution of aeolian materials.

Problems were encountered in correlating sand percentages as determined by the hydrometer method with values obtained by sieve separation of those soils containing large amounts of ash. The sand percentages obtained by hydrometer analysis, with particle density

Table 9

PARTICLE SIZE DISTRIBUTION, SAND FRACTIONS AND SPECIFIC GRAVITY OF FINE SANDS

Profile and Horizon		Sample Depth(cm)	Particle Size %S	%Si	%C	Sand Fractions % of Total Sand VCS	CS	MS	FS	VFS	Specific Gravity, % of FS > 2.94	2.94 -2.75	2.75 -2.50	< 2.50
Alpine Dystric Brunisols														
T9	Ah	0-1	45	45	10	-*	-	-	-	-	0.5	-	-	55.7
	Bm	1-6	32	65	3	0.0	2.8	7.8	43.0	46.4	0.6	-	-	66.4
	IIBC	7-40	49	40	11	1.8	6.6	8.7	49.7	33.2	0.9	60.4	39.0	0.1
T17	Ah	0-3	23	72	5	0.0	1.0	3.7	59.2	36.1	0.1	-	-	-
	Bm	3-20	20	67	13	5.7	11.1	10.3	20.5	52.4	0.4	2.5	71.8	25.2
	IIBC	20-40	43	48	9	4.0	14.2	14.7	25.6	41.5	1.0	15.7	83.3	0.0
	IICk	40-70	53	39	8	3.5	6.9	9.5	65.0	15.1	0.6	-	-	0.0
L1	Ah	0-5	67	29	4	4.8	10.1	23.9	51.1	10.1	1.0	-	-	32.0
	Ahe	5-9	41	49	10	5.8	16.3	20.5	44.6	12.8	tr	-	-	tr
	Bm	9-17	29	58	13	4.3	19.4	21.6	31.6	23.1	1.1	-	-	1.5
	IIBC	17-24	41	41	18	8.7	25.3	22.7	29.1	14.2	1.2	-	-	0.0
	IIC	24-50	42	38	20	5.0	23.8	27.0	32.2	12.0	-	-	-	0.0
Alpine Eutric Brunisols														
T3	Ah	0-5	26	69	5	0.9	2.6	11.7	45.8	39.0	0.3	-	14.5	85.5
	Bm	5-13	24	72	4	1.7	5.2	7.5	27.4	58.2	0.1	0.6	38.6	60.8
	IIBC	13-30	30	57	13	1.4	9.2	14.1	27.7	47.6	0.4	1.1	98.8	tr
	IIICk	30-60	61	33	6	6.2	12.9	18.2	33.8	28.9	0.3	43.1	56.3	tr
T55	Ah	0-15	42	47	11	2.6	10.5	16.9	45.7	24.3	-	-	-	-
	Bmk	15-18	45	53	2	10.1	22.5	14.8	27.5	25.1	0.5	-	-	-
	IICk	18-50	72	20	8	12.7	28.1	21.9	23.7	13.6	0.8	83.0	16.0	tr

Table 9 (cont.)

Profile and Horizon		Sample Depth(cm)	Particle Size %S	%Si	%C	Sand Fractions % of Total Sand VCS	CS	MS	FS	VFS	Specific Gravity, % of FS > 2.94	2.94 -2.75	2.75 -2.50	< 2.50
Orthic Regosol														
T7	Ahk1	0-5	30	67	3	0.3	1.2	6.8	43.9	47.8	tr	8.5	57.6	34.0
	Ahk2	5-15	30	67	3	0.0	0.4	2.2	46.9	50.5	0.6	29.6	47.3	22.5
	IICk	15-60	60	31	9	6.1	10.3	8.4	34.0	41.2	0.2	75.7	22.5	tr
Rego Humic Gleysol														
T27	Ahg	0-10	62	35	3	6.7	21.7	21.4	27.2	23.0	-	-	-	-
	Cg1	10-35	33	62	5	11.4	18.7	17.1	27.6	25.2	2.6	-	-	0.0
	Cg2	35-55	28	51	21	6.5	17.2	16.9	31.9	22.5	0.9	-	-	0.0
Earth Hummocks														
T24	Ah		22	73	5	0.0	0.0	0.4	54.0	44.6	-	-	-	-
	Ah + Bm1		17	78	5	0.0	1.9	3.2	62.5	32.4	0.3	-	-	78.8
	Bm2		14	83	3	0.0	0.0	1.6	58.0	40.5	0.0	-	-	89.8
	Bm3		18	80	2	0.0	5.5	10.3	50.7	33.5	0.0	-	-	83.1
	C		16	81	3	2.1	4.2	3.1	55.4	35.2	tr	-	-	47.6
	IICg2		17	52	31	6.9	26.4	22.6	27.2	17.9	0.7	-	-	0.0

* - indicates the value was not determined

Figure 5. Cumulative Particle Size Distribution Curves of the Ah, Bm and IICk Horizons of Alpine Eutric Brunisol T3

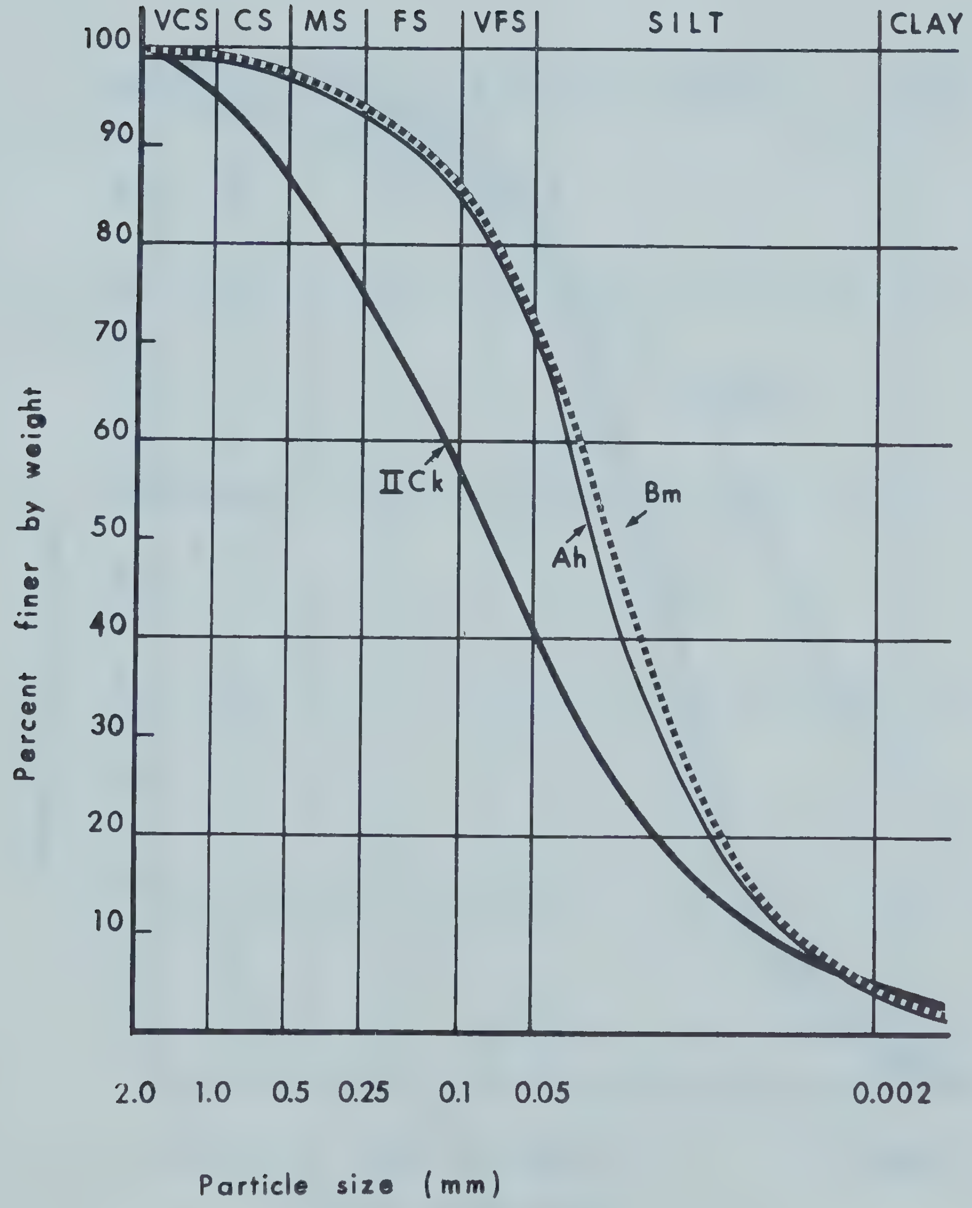
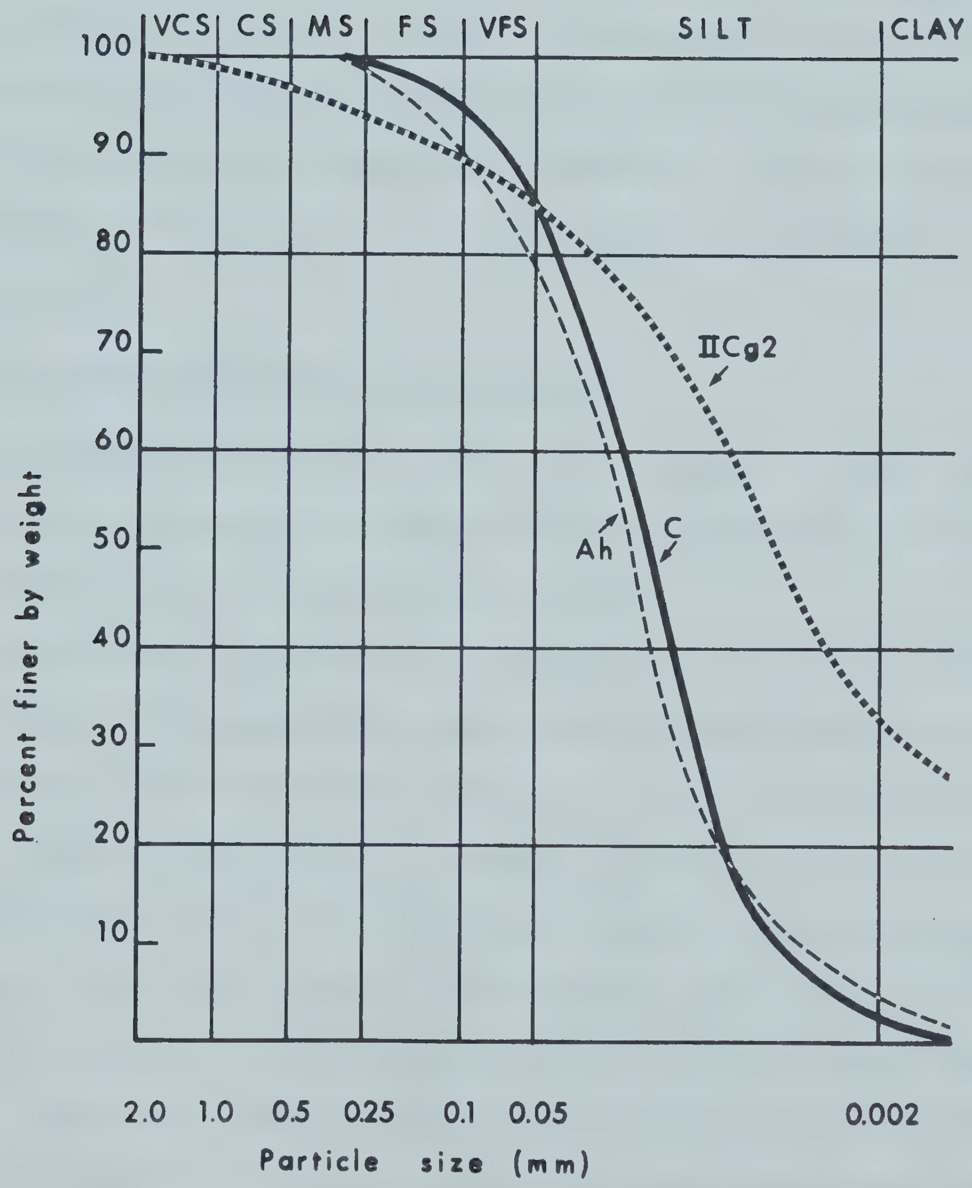


Figure 6. Cumulative Particle Size Distribution Curves of the Ah, C and IICg2 Horizons of the Earth Hummocks T24



accounted for, were lower than those obtained by subsequent sieve separation of the samples used in the hydrometer analysis. The suggested reason is that the non-spherical shape, vesicular nature and low particle density of the ash particles causes them to settle at a slower velocity than predicted by Stoke's Law. Thus a particle with a diameter in the very fine sand class may settle at the velocity expected of a silt-sized particle. As the modal size class of the ash is very fine sand to coarse silt (Figure 6) a slight deviation from Stoke's Law could produce a fairly large over-estimation of the silt content.

Specific Gravity Separations of Fine Sand

The fine sands of selected soils were separated into four fractions based on specific gravity in order to obtain a preliminary indication of the mineral suite of these soils (Table 9).

The 2.50 s.g. separation was made primarily to separate volcanic glass shards. Some quartz and potash and plagioclase feldspars (mainly of volcanic origin) can also be expected in this fraction (Pettapiece, 1970). Those minerals with s.g. between 2.50 and 2.75 include quartz, some carbonates, potash and plagioclase feldspars, and some volcanic fragments. The 2.75 - 2.94 s.g. fraction will include the bulk of the carbonate minerals and some pyroxenes, amphiboles and volcanic fragments. Such heavy minerals as the ortho and clino pyroxenes, amphiboles, zircon, tourmaline and chlorite have specific gravities greater than 2.94.

The high content of minerals with s.g. <2.50 in the surface horizons of the well-drained soils and in the earth hummocks confirms

the presence of volcanic ash in these soils (Table 9). The absence of ash in the lower horizons is also clearly illustrated. The earth hummock soil (T24) is composed predominantly of ash down to the IICg2 horizon which is a lacustrine deposit.

The increase of carbonate minerals with depth is illustrated for those soils developed on calcareous parent materials.

Heavy mineral content is generally low in all soils, especially when high contents of volcanic ash are present.

Bulk Density

Bulk density values (Table 10) for some of the selected soils indicate that typical values for Ah horizons are in the order of 0.6 to 0.8 g cm^{-3}. These low values result from the high organic content and turfy nature of the surface horizons and also the high volcanic ash content. Density values increase sharply with the change to the till-colluvium of the IIBC or IIC horizons. Bulk densities were not determined on stony soils.

Particle Density

Particle densities (Table 10) also reflect the differences in parent materials. The A and B horizons, with a significant volcanic ash component, have low particle densities while the IIC horizons, made up of colluvium and till, have greater contents of heavier minerals.

Moisture Relationships

The 0.1 and 15 bar moisture percentages (Table 10) indicate energy relationships of water retention in these soils. Both 0.1 and 15 bar

Table 10 BULK DENSITY, PARTICLE DENSITY, AND MOISTURE DATA FOR SELECTED SOILS

Profile and Horizon		Sample Depth (cm)	Bulk Dens. g cm^{-3}	Particle Density g cm^{-3}	Moisture Relationships % on O.D. wt. basis 1/10 bar	15 bar
Alpine Dystric Brunisols						
T9	Ah	0-1	-	-	92	46
	Bm	1-6	-	2.16	98	33
	IIBC	7-40	-	2.80	38	6.0
T17	Ah	0-3	0.6	2.30	72	34
	Bm	3-20	0.8	2.58	-	-
	IIBC	20-40	-	2.73	15	4.8
	IICk	40-70	-	2.76	24	6.0
L1	Ah	0-5	0.6	-	72	34
	Ahe	5-9	-	2.52	48	17
	Bm	9-17	0.8	2.52	54	20
	IIBC	17-24	-	2.82	23	9.4
	IIC	24-50	1.6	2.82	25	8.8
Alpine Eutric Brunisols						
T3	Ah	0-5	-	-	88	39
	Bm	5-13	-	2.41	74	22
	IIBC	13-30	-	2.81	34	11
	IICk	30-60	-	2.77	27	23
T55	Ahk	0-15	-	-	94	38
	Bmk	15-18	-	2.42	86	19
	IICk	18-50	-	2.81	24	6.4
Orthic Regosol						
T7	Ahk1	0-5	0.6	-	100	38
	Ahk2	5-15	0.8	-	79	24
	IICk	15-60	-	2.91	20	3.1
Rego Humic Gleysol						
T27	Ahg	0-10	-	2.52	72	14
	Cg1	10-35	-	2.83	32	8.1
	Cg2	35-55	-	2.93	34	12
Earth Hummocks						
T24	Ah		0.4	-	100	41
	Ah+Bm1		0.6	2.20	120	24
	Bm2		0.6	2.35	92	14
	Bm3		0.6	2.33	86	17
	C		-	2.40	83	8.1
	IICg2		1.4	2.88	36	12

water content are highest in the Ah horizons which reflects organic matter content. The fairly high 0.1 bar water in the Bm horizons is probably due to retention by organic matter and by amorphous colloids. A sharp decrease in water retention is evident in the IIBC and IIC horizons.

Soil Reaction

Soil pH values, measured in both water and $CaCl_2$ suspensions, are reported in Table 11. The Alpine Dystric Brunisols are very strongly to strongly acid (paste pH) in the turf and Ah horizons, and Bm horizons are strongly to medium acid (paste pH 5.4 - 5.8). These pH ranges are favorable for the mobilization of aluminum and iron (Acquaye and Tinsley, 1965). The parent materials may be alkaline or acid depending on the geologic source.

The Alpine Eutric Brunisols display somewhat different pH trends. The turfs and Ah horizons may be as acid as the Dystric soils but the Bm horizons are less acid and may be moderately alkaline as in those weakly-developed soils on strongly calcareous parent materials.

Orthic Regosol T7 is moderately alkaline throughout the profile, reflecting the influence of a very calcareous parent material. The turf and Ah horizons of some of the Orthic Regosols may be slightly acid.

The Gleysolic soils are often moderately to slightly acid in the surface horizons and pH generally increases to alkaline in the Cg horizons.

The earth hummock soils are acid throughout the profile, with pH increasing slightly with depth.

Table 11 SOIL REACTION, ORGANIC C, ORGANIC MATTER, NITROGEN, C/N, AND IRON AND ALUMINUM VALUES FOR SELECTED SOILS

Profile and Horizon		Sample Depth (cm)	pH		Org. C%	O.M. %	N %	C/N	$CaCO_3$ equiv.%	Oxalate		Pyrophosphate	
			H_2O	$CaCl_2$						%Fe	%Al	%Fe	%Al
Alpine Dystric Brunisols													
T9	Ah	0-1	4.9	4.1	13.5	23	0.8	17	-	0.71	0.63	0.40	0.22
	Bm	1-6	5.6	4.6	8.1	14	0.6	12	-	1.30	4.60	0.93	0.34
	IIBC	7-40	7.6	7.1	0.6	1	0.1	6	26.0	0.85	0.16	-	-
T17	L		5.4	4.7	12.0	21	0.9	13	-	-	-	-	-
	Ah	0-3	5.3	4.6	10.1	17	0.7	15	-	0.52	0.68	0.52	0.17
	Bm	3-20	5.8	4.8	3.3	6	0.3	12	-	0.60	2.00	0.67	0.13
	IIBC	20-40	6.8	6.1	0.7	1	0.1	10	-	0.25	0.26	-	-
	IICk	40-70	7.8	7.2	-	-	-	-	36.5	-	-	-	-
L1	Ah	0-5	4.7	4.0	12.7	22	0.9	15	-	-	-	0.42	0.40
	Ahe	5-9	5.0	4.2	4.5	8	0.3	14	-	0.96	0.40	0.42	0.06
	Bm	9-17	5.4	4.5	4.2	7	0.3	14	-	1.41	1.60	1.27	0.06
	IIBC	17-24	5.3	4.4	0.4	1	0.1	5	-	0.62	0.30	-	-
	IIC	24-50	5.5	4.7	-	-	-	-	-	-	-	-	-
Alpine Eutric Brunisols													
T3	L		5.4	4.9	25.3	44	1.9	14	-	-	-	-	-
	Ah	0-5	5.7	5.1	11.5	20	1.0	12	-	0.75	0.68	0.40	0.13
	Bm	5-13	7.1	6.3	3.9	7	0.4	10	2.4	1.17	2.40	0.42	0.40
	IIBC	13-30	7.5	7.0	0.9	2	0.1	8	0.5	0.75	0.44	-	-
	IIICk	30-60	7.8	7.1	-	-	-	-	53.6	-	-	-	-

- continued -

Table 11 (con't)

Profile and Horizon		Sample Depth(cm)	pH H_2O	pH $CaCl_2$	Org. C%	O.M. %	N %	C/N	$CaCO_3$ equiv.%	Oxalate %Fe	Oxalate %Al	Pyrophosphate %Fe	Pyrophosphate %Al
Alpine Eutric Brunisols (continued)													
T55	Ahk	0-15	7.3	6.7	10.0	17	0.8	12	0.5	0.33	0.52	–	–
	Bmk	15-18	7.6	7.0	4.4	8	0.5	9	0.6	0.35	1.22	–	–
	IICk	18-50	7.6	6.9	–	–	–	–	–	0.17	0.24	–	–
Orthic Regosol													
T7	Ahk1	0-5	7.9	7.2	8.6	15	0.9	10	21.8	–	–	–	–
	Ahk2	5-15	8.0	7.1	5.2	9	0.5	9	35.0	–	–	–	–
	IICk	15-60	8.0	7.4	–	–	–	–	91.4	–	–	–	–
Rego Humic Gleysol													
T27	Ahg	0-10	6.3	5.3	4.5	8	0.4	10	–	–	–	–	–
	Cg1	10-35	5.8	5.1	–	–	–	–	–	–	–	–	–
	Cg2	35-55	6.9	6.3	–	–	–	–	–	–	–	–	–
Earth Hummocks													
T24	Ah		5.3	4.5	12.0	21	0.9	13	–	0.68	1.30	0.59	0.45
	Ah +Bm1		5.9	5.1	6.4	11	0.5	13	–	0.85	2.44	0.56	0.28
	Bm2		6.1	5.2	2.2	4	0.2	9	–	0.66	2.50	0.13	0.06
	Bm3		6.1	5.5	2.8	5	0.3	9	–	0.82	4.26	0.19	0.13
	C		6.5	5.2	–	–	0.1	–	–	0.32	2.05	0.05	0.00
	IICg2		6.1	4.9	–	–	0.1	–	–				
										0.32	0.18	–	–

The $CaCl_2$ pH values, which are intended to more closely represent intrinsic soil reaction characteristics (Schofield and Taylor, 1955; Peech, 1965) show similar trends to the water pH values and are usually 0.5 to 0.7 pH units lower than the water values.

Organic Matter and Nitrogen

Organic carbon contents (Table 11) are high (10-13%) in the Ah horizons and may be as high as 4 to 8% in Bm horizons. Total nitrogen in Ah horizons of 0.7 to 1.0% (Table 11) are common. Nitrogen content decreases rapidly with depth, as does organic matter content. C/N ratios are typically in the range of 12 to 14 but may be as high as 17 (Table 11).

These results concur with those reported for other alpine areas (Retzer, 1956; Nimlos and McConnell, 1965). Sneddon, Lavkulich and Farstad,(1972) reported good correlations between organic carbon content and such soil properties as hygroscopic and 15 bar water, volcanic ash content, cation exchange capacity, exchangeable K, total N, and total S for alpine soils in British Columbia.

Calcium Carbonate Equivalent

$CaCO_3$ equivalent (Table 11) usually increases with depth due to carbonation and the presence of aeolian materials in surface horizons. The Alpine Dystric Brunisols, with acidic sola, have free carbonates only in the C horizons of those profiles developed on calcareous parent materials. The Alpine Eutric Brunisols may have free carbonates present in the Ah and Bm horizons.

Very high $CaCO_3$ equivalents were obtained for some soils developed on limestone-derived colluvium. Orthic Regosol T7 is an example with

$CaCO_3$ equivalent values of 21.8% in the Ahk1, 35.0% in the Ahk2, and 91.4% in the IICk.

Iron and Aluminum

The acid ammonium oxalate extraction is intended to extract amorphous Fe and Al oxides. Oxalate-extractable Fe and Al values are used to differentiate various types of B horizons in the System of Soil Classification for Canada (C.S.S.C., 1970).

Considerable amounts of Fe and Al were extracted by the oxalate procedure in several of the soils with the greatest amounts being extracted from B horizons (Table 11). The Alpine Dystric Brunisols have especially high levels of oxalate-extractable Fe and Al in the B horizons (1.30% Fe and 4.60% Al in the Bm of T9). The 5.9% total Fe plus Al of the Bm of T9 is considerably higher than the 1.01% total in the underlying IIBC. Similar trends may be noticed for other Alpine Dystric Brunisols (Table 11 and Appendix). Ammonium oxalate extracts high amounts of Fe and Al from the volcanic ash which is present in the sola of these soils but not in the IIC horizons. Fe and Al values for the relatively unweathered ash from the C horizon of T24, which occurs at a depth of 50 cm below the present soil surface, total 2.37% which illustrates the high levels of Fe and Al ammonium oxalate extracts from ash.

The pyrophosphate extraction procedure extracts Fe and Al that is associated with organic matter. As evidenced from data in Table 11, pyrophosphate extracted less Fe and much less Al from every horizon than the oxalate extraction. It appears that there is considerable amount of Fe associated with organic matter in the B horizons but

very little Al.

Cation Exchange Characteristics

Exchangeable acidity, determined by the barium acetate method, is high in surface horizons where pH is low and amorphous sesquioxide content is high, and decreases with depth and increasing pH (Table 12). The high levels of Al present likely contribute to the exchangeable acidity.

Ca and to lesser degrees Mg, are the most prevalent exchangeable bases present, with Na and K being present in minor concentrations (Table 12). Percentage base saturation, calculated as the sum of exchangeable bases divided by total exchange capacity as measured with NH_4OAc, is extremely low in the A and B horizons of the Alpine Dystric Brunisols and in the earth hummocks (Table 12). Similar results have been reported for alpine soils in British Columbia (Sneddon, Lavkulich and Farstad, 1972).

Soils with high contents of amorphous colloids characteristically have a high pH-dependent cation exchange capacity (Fields, *et al.*, 1952; Birrell and Gradwell, 1956; Aomine and Jackson, 1959; Clark *et al.*, 1966). When cation exchange capacity (CEC) is obtained using a salt buffered at neutral pH (NH_4OAc) the pH-dependent component of the CEC is measured and the result may be considerably higher than the permanent charge component of the CEC obtained by extraction with a neutral salt (Coleman, *et al.*, 1959; Clark, 1965). A preliminary investigation into this aspect of pH-dependent CEC yielded the results shown in Table 13.

Table 12 CATION EXCHANGE CHARACTERISTICS AND AVAILABLE PHOSPHORUS OF SELECTED SOILS

Profile and	Horizon	Sample Depth(cm)	Exch. Acidity	Na	K	Ca	Mg	TEC[1]	Base Satn. %	Avail. P ppm
			m.e./100g.							
Apline Dystric Brunisols										
T9	Ah	0-1	18.4	0.1	0.4	1.5	0.3	34.0	7.8	5
	Bm	1-6	20.8	0.1	0.1	0.6	0.1	45.8	1.7	4
	IIBC	7-40	-	-	-	-	-	5.7	(100)	30
T17	L	4-0	16.6	0.1	1.8	3.0	2.0	32.4	21.3	15
	Ah	0-3	13.8	0.1	0.4	1.4	0.4	22.9	10.1	4
	Bm	3-20	7.8	tr	0.1	0.8	0.1	5.4	18.9	10
	IIBC	20-40	1.3	tr	tr	3.0	2.3	3.0	(100)	6
	IICk	40-70	-							16
L1	Ah	0-5	20.8	0.3	0.9	3.3	1.3	35.8	16.2	15
	Ahe	5-9	12.6	0.1	0.1	0.5	0.4	21.5	5.1	2
	Bm	9-17	12.5	0.1	0.1	0.2	0.3	25.7	2.7	0
	IIBC	17-24	5.4	0.1	tr	0-0	0.2	9.0	3.0	1
	IIC	24-50	3.0	tr	tr	1.5	1.0	7.7	30.8	1
Alpine Eutric Brunisols										
T3	L	3-0	20.4	tr	1.5	46.0	13.2	78.9	77.0	6
	Ah	0-5	10.0	0.1	0.3	26.0	7.5	43.0	78.8	1
	Bm	5-13	-	0.1	0.1	21.8	5.8	29.8	93.5	2
	IIBC	13-30	-	tr	tr	10.5	4.0	11.0	(100)	1
	IICk	30-60	-	-	-	-	-	2.0	(100)	10
T55	Ahk	0-15	-	tr	0.2	39.0	5.6	44.2	(100)	1
	Bmk	15-18	-	-	-	-	-	30.9	(100)	2
	IICk	18-50	-	-	-	-	-	10.2	(100)	16

Table 12 (cont.)

Profile and Horizon		Sample Depth(cm)	Exch. Acidity	Na	K	Ca	Mg	TEC[1]	Base Statn.	Avail. P
			m.e./100g.						%	ppm
Orthic Regosol										
T7	Ahk1	0-5	-	-	-	-	-	50.3	(100)	3
	Ahk2	5-15	-	-	-	-	-	30.6	(100)	0
	IICk	15-60	-	-	-	-	-	2.7	(100)	0
Rego Humic Gleysol										
T27	Ahg	0-10	5.0	0.1	0.1	6.8	1.5	17.9	47.5	4
	Cg1	10-35	1.4	tr	0.1	4.0	2.0	3.9	(100)	2
	Cg2	35-55	0.3	tr	0.1	4.9	2.0	6.0	(100)	0
Earth Hummocks										
T24	Ah		16.1	0.3	0.2	1.0	0.3	32.2	5.6	6
	Ah+Bm1		10.6	0.2	tr	0.8	0.1	24.0	4.6	16
	Bm2		5.4	0.2	tr	0.5	0.2	11.9	7.6	2
	Bm3		6.0	0.1	0.1	0.2	0.2	19.2	3.1	2
	C		2.4	tr	0.1	2.5	0.3	6.5	22.4	15
	IICg2		2.1	tr	0.2	3.5	1.6	8.5	42.4	8

[1]TEC = Total Exchange Capacity

Table 13 CATION EXCHANGE CAPACITIES AS MEASURED WITH NH_4OAc (pH7) AND WITH NaCl

Profile and Horizon		pH7 CEC	Permanent Charge CEC
		m.e./100g	
T9	Ah	34.0	8.6
	Bm	45.8	4.8
	IIBC	5.7	6.9
T15	Ah1	24.5	6.3
	Bm1	32.9	6.1
	IIC	7.1	5.0

A considerable amount of pH-dependent CEC occurs in the Ah and especially the Bm horizons as evidenced by the wide differences in CEC values obtained by the two methods. These are also the horizons of maximum amorphous Fe and Al content.

Available Phosphorus

Results reported in Table 12, show generally low levels of available P in most of the soils, especially in the B horizons. The low levels of available P may be related to the high P-fixing capacity of amorphous Fe and Al oxides (Saunders, 1965).

Clay Minerals

X-ray diffraction - In order to gain some understanding of the types of minerals present in the clay fractions of alpine soils, horizons from two Alpine Dystric Brunisols, one Rego Humic Gleysol, and one earth hummocks profile were selected for study. Minerals present, as estimated from x-ray diffraction patterns, are tabulated in Table 14 , and

Table 14 MINERALOGY OF THE TOTAL CLAY FRACTION OF SELECTED SOILS AS ESTIMATED FROM X-RAY DIFFRACTION PATTERNS

Profile and Horizon		Qtz.[1]	Kaol.[2]	Ill.[3]	Verm.[4]	Chl.[5]	Total cryst.[6]
Alpine Dystric Brunisols							
T9	Bm						nil
	IIBC	x[7]	xx	xxx	—— x ——		med-high
T15	Ah1		x	xxx	—— x ——		med.
	Bm1			xx	—— x ——		low
	C		x	xxx	—— xx ——		high
Rego Humic Gleysol							
T27	Ahg		xx	xxx	xx	xx	high
	Cg1		xx	xxx	xx	xx	high
	Cg2		xxx	xxx	x	x	high
Earth Hummocks							
	Ag			x	—— x ——		low
	Ah+Bm1			x	—— x ——		low
	IICg2	x	xxx	xxx	xx	xx	high

1 Quartz - from 4.26 A° peak
2 Kaolinite - from 7.1A° peak that disappears when heated to 550°
3 Illite (mica) - from 10A° peak of Mg-glycolated sample
4 Vermiculite - from 14A° Mg-glycolated peak that collapses to 10A° when K sat'd and heated to 550°
5 Chlorite - from 14A° peak that remains when K sat'd and heated
6 Total crystalline material - an estimate of the amount of crystalline materials in the sample
7 x = trace (<10%), xx = minor (10-25%), xxx = major (>25%)

A blank space indicates no evidence of the mineral

Figure 7. X-ray Diffraction Patterns of the Total Clay Fractions From Alpine Dystric Brunisols T15 and T9

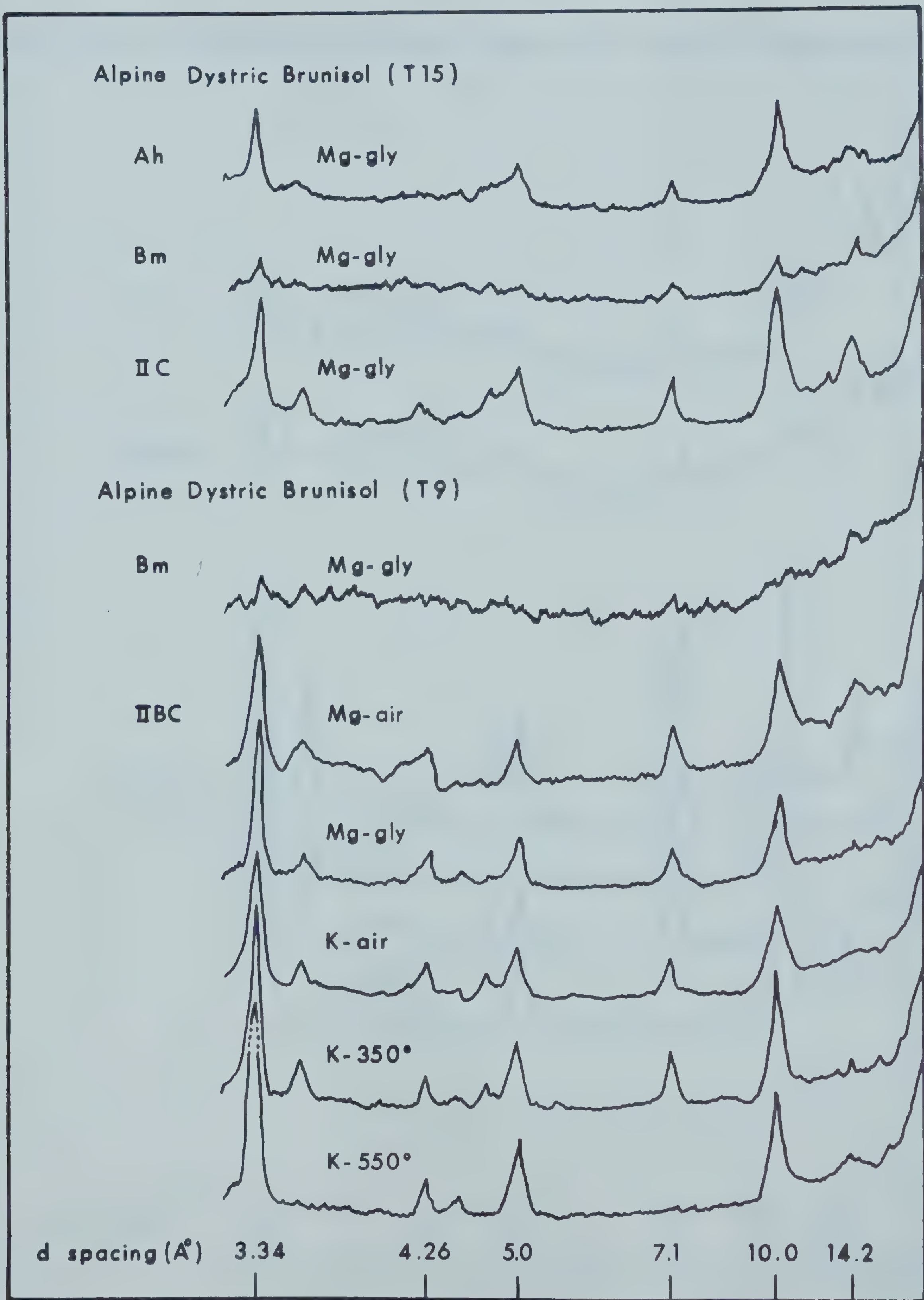
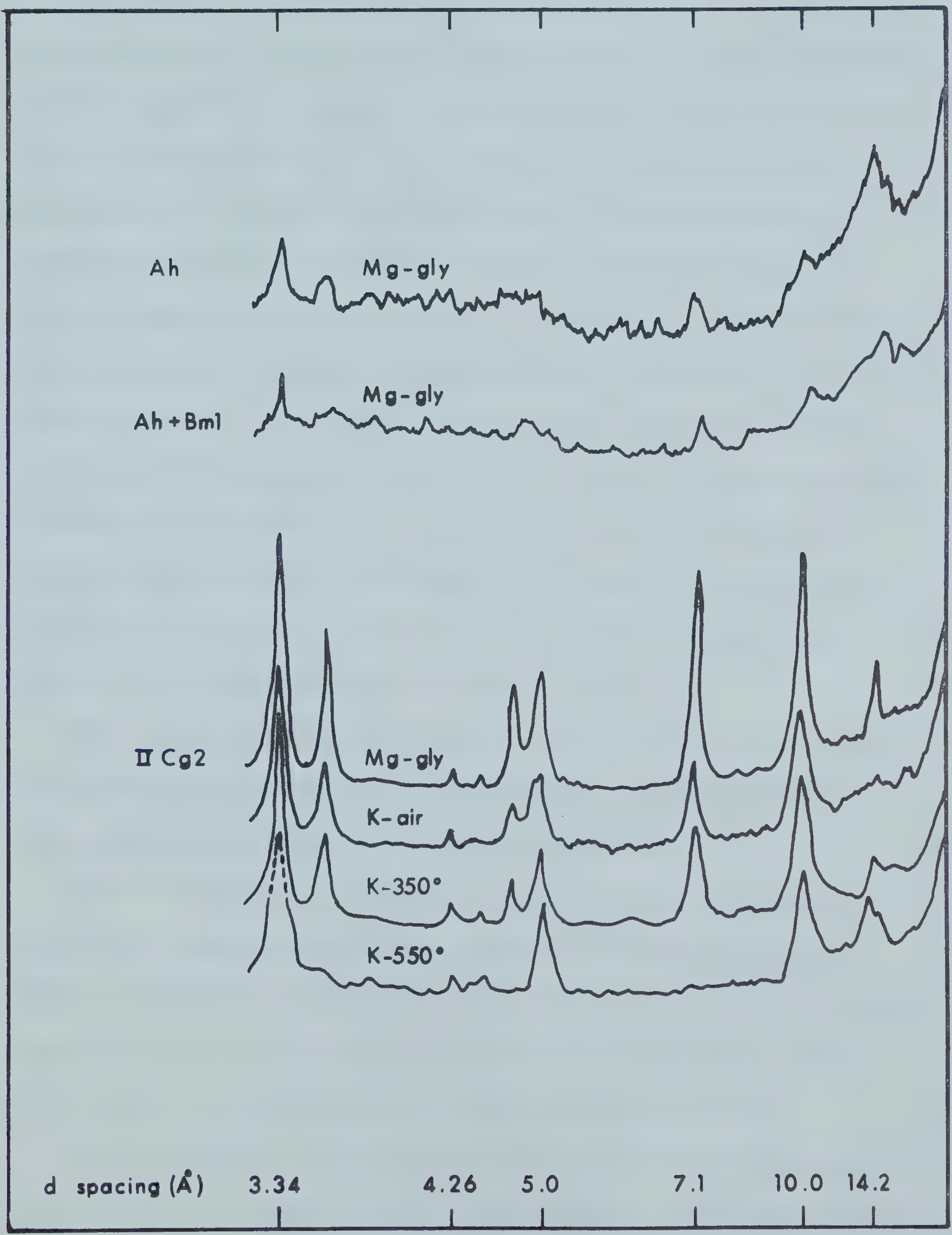


Figure 8. X-ray Diffraction Patterns of the Total Clay Fractions of the Ah, Ah+Bm1 and IICg2 Horizons from the Earth Hummocks T24



diffraction patterns of the clay fractions of Alpine Dystric Brunisol T15 and earth hummocks T24 are traced in Figures 7 and 8.

The importance of amorphous materials in the sola of the Alpine Dystric Brunisols is shown by the limited amounts of total crystalline material (Table 14). The Ah1 of T15 has moderate crystallinity with the major component being illite. Traces of kaolinite and a non-expanding 14 A^{o} component are also present. The Bm1 horizon is dominated by amorphous material with some illite and a trace of chlorite-vermiculite being present. The minerals in these horizons are not well crystallized as evidenced by broad peaks of the diffraction patterns. The diffraction pattern of the Bm of T9 showed no evidence of crystalline minerals at all. The IIBC and IIC horizons of these soils have much greater amounts of crystalline minerals. Illite is again the major clay mineral with minor to trace amounts of kaolinite, vermiculite, and chlorite. Evidence of quartz was detected in the diffraction pattern of the IIBC of T9.

Well-crystallized minerals predominate in the Rego Humic Gleysol with no indication of an amorphous component. Illite dominates with lesser amounts of kaolinite, vermiculite and chlorite.

The earth hummocks, as mentioned previously, are composed of volcanic ash overlying lacustrine sediments. The clay mineralogy reflects this with the IICg2 being almost identical with the alluvial-lacustrine Cg2 of the Gleysol and the Ah and Ah-Bm1 being similar to the poorly crystalline surface horizons of the Brunisols.

No clay minerals that expanded beyond the 14A^{o} peak when glycolated (indicative of the smectite group) were evident in any of the samples examined.

Table 15 RESULTS OF NaOH DISSOLUTION OF AMORPHOUS ALUMINOSILICATES IN CLAY FRACTIONS

Profile and Horizon		SiO_2 % *	Al_2O_3 % *	Amorphous** %	$\frac{SiO_2}{Al_2O_3}$ +
T9	Ah	13.0	4.4	19.4	5.0
	Bm	29.6	26.1	61.9	1.9
	IIBC	5.9	2.0	8.7	5.0
T15	Ah1	11.6	3.8	17.1	5.1
	Bm1	15.2	9.4	27.3	2.7
	C	7.6	3.1	11.8	42.

* Percent of clay fraction

** % Amorphous = (%SiO_2 + % Al_2O_3)/0.9. The 0.9 factor corrects for 10% water in amorphous material.

\+ Molar ratio

<u>NaOH dissolution</u> - NaOH dissolution of the clay fractions of two Alpine Dystric Brunisols was performed to obtain an estimate of the amorphous component. The greatest amounts of amorphous aluminosilicates were present in the Bm horizons with the Bm1 of T9 containing 61.9% (Table 15). SiO_2/Al_2O_3 molar ratios reflect the large relative increase of Al_2O_3 in the Bm horizons.

The same trends have been noted in the B horizons of podzols (Brydon, Kodama and Ross, 1968; Yuan, 1969). High levels of amorphous aluminosilicates and low SiO_2/Al_2O_3 ratios in B horizons of podzols derived from volcanic ash have been reported by Beke and Pawluk (1971).

PART V. SOIL FORMATION AND CLASSIFICATION

Discussion on Soil Formation

The classical factors of soil formation, namely parent material, climate, topography and vegetation control the balance between the pedogenic processes of additions, removals, transfers and transformations which act in combination in the formation of a soil (Simonson, 1959). The characteristics acquired by a soil body therefore reflect the environmental parameters involved in its formation.

Most of the alpine soils of the Sunshine area have developed on thin glacial till and colluvial deposits which have significant amounts of volcanic ash incorporated into the upper few centimeters. Due to mass-wasting and frost action processes unconsolidated materials move downslope burying old surfaces, disrupting soil horizons, and mixing materials together on the steep slopes. Bedrock often occurs within 50 cm of the surface. The till and colluvium are generally sandy loam to loam in texture with high contents of coarse fragments and variable reaction and carbonate content.

Textures of surface horizons are usually silt loam, with silt content often being 60%. High silt content in surface horizons of alpine soils is well known and has been attributed to frost weathering (Costin, Hallsworth and Woof, 1952; Ragg and Bibby, 1966; Romans, Stevens and Robertson, 1966), greater biological and chemical activity in the warmer surface horizons (Retzer, 1956), and the composition and texture of parent rocks (Costin, Hallsworth and Woof, 1952; Van Ryswyk, 1969). Aeolian deposits (including volcanic ash) seem to be prevalent in alpine areas and have been suggested as a source for silt-sized

material (Stepanov, 1962; Baptie, 1968; Van Ryswyk, 1969; Sneddon, Lavkulich and Farstad, 1972).

The occurrence of tephra is well known for the northwestern United States, southern British Columbia and southern Alberta (Powers and Wilcox, 1964; Nasmith, Mathews and Rouse, 1967; Westgate and Driemanis, 1967; Westgate, Smith and Nichols, 1969; Westgate, Smith and Tomlinson, 1970).

Volcanic ash is considered to be the major source of the high silt content in the sola of the Sunshine soils due to several reasons. The presence of ash has been established in the area, and the shape of particle size curves, the sand mineralogy results, particle densities and the "gritty" feel of the silt-sized material indicate the presence of ash in these soils.

In an area where snow cover persists for about 10 months and where temperatures are cold and may be below freezing any day of the year, the amount of energy available to the soil system is low. Soil water content may be limiting for pedogenic development when soil temperatures are at a maximum in August. Retzer (1956) used the term "cryopedogenic region" to describe alpine and arctic areas.

The surface horizons receive the greatest amount of energy and have the greatest biological activity. A densely-rooted organic turf layer has developed on the surface of most of the alpine soils. This characteristic turf led Retzer (1956) to name the great soil group for the well-drained alpine soils the Alpine Turf Great Group. The turf is likely a result of the growth habit of the alpine flora and may result from lower temperatures at depth early in the year causing greater rooting activity at the surface although average maximum rooting

depth is about 40 cm. The densely-rooted turf is important to the stability of these soils.

The cold alpine temperatures restrict microbial activity in the soils resulting in net accumulation of organic material in surface horizons. Ah horizons characteristically have high amounts of organic carbon and high levels of nitrogen. C/N ratios are low, in the order of 12-14. Mechanical mixing of the organic and mineral components has resulted in a dark colored moder type of Ah called slope or alpine moder by Bernier (1968) in which true organo-mineral complexes are rare. The large amounts of organic matter and volcanic ash result in bulk densities in the order of 0.6 to 0.8 g cm^{-3} and loose granular structure.

Evidence of eluviation was noticed in only one soil which was within the upper limits of the present forest-tundra ecotone and may have been covered by coniferous vegetation at some time in the recent past. Soil leaching has been reported from various areas under alpine vegetation, especially under ericaceous shrub communities (Baptie, 1968; Van Ryswyk, 1969; Sneddon, Lavkulich and Farstad, 1972) however no visible evidence of leaching was observed in soils under true alpine tundra vegetation in the Sunshine area.

Ah horizons vary in depth and organic matter content depending on slope stability and position, time of snow release, and the amount and type of plant cover (which is often dependent on the foregoing parameters). Soils in reasonably stable slope positions with at least moderately early snow release and a continuous cover of herbs and sedges tend to show the greatest Ah expression. Soils on active slopes may have fairly deep cumulic Ah horizons especially when they

occur on a slight break in the slope. Late snow release restricts plant growth and thus accumulation of organic matter.

Most of the Ah horizons are moderately to strongly acid however those developed on calcareous parent materials in positions of severe wind desiccation may be alkaline and have high contents of free carbonates.

B horizons, when present, are of reddish hues and often high chroma. The reddest B horizons are associated with significant ash content which weathers easily to produce large amounts of amorphous iron and aluminum oxides. Due to soil creep processes,organic material from above and C or IIC material from below may be mixed into the B horizons. This disruption and mixing of soil horizons is evidence of the active role slope plays in genesis of high mountain soils. The B horizons contain low amounts of clay (5-10%) and about 60% silt which is the same particle size distribution found in Ah horizons and is related to the presence of silt-sized ash. No evidence of illuvial clay or silt was observed. Development of the Bm horizons is considered to be essentially *in situ* weathering of mainly volcanic ash materials with limited transfers of aluminum and iron in solution.

Some of the B horizons may be older geologically than their A horizons due to more than one period of deposition of aeolian material. The accumulation of loessial material on snow and its subsequent deposition on the soil surface seems to be of considerable importance in mountainous areas (Warren Wilson, 1958; Stepanov, 1962) and has been observed by the author in various alpine areas of the Rocky Mountains. This process may account for some of the deep turfs that have large amounts of mineral material within them and seem to be

of a cumulative nature.

Genesis of the Orthic Regosols is essentially limited to accumulation of organic matter in surface horizons. These soils are present in areas of very active soil movement where the soils are continually truncated, in windswept, zerophytic locations where essentially no effective soil leaching occurs and free carbonates are present at the soil surface, and in late snowbed locations where the short snow-free period greatly restricts plant growth and soil development. Ah horizons in the snowbed areas are often absent or may occur under clumps of vegetation.

The Alpine Eutric Brunisols seem to represent a continuous series of development from the Orthic Regosols to the Alpine Dystric Brunisols. Alpine Eutric Brunisols, which represent the least amount of increase in pedogenic development over the Orthic Regosols, occur in association with the Regosols on the steep windswept slopes and in the late snowbed areas. Weakly developed Bm horizons are present which have slightly redder hues and lower pH than the C horizons but are discontinuous and are severely disrupted by soil creep. Alpine Eutric Brunisols that occur on relatively snow-free ridges at high elevations under *Kobresia* communities have densely-rooted turfs overlying deep, black Ah horizons and Bm horizons that are thicker and more continuous than those described above. These B horizons have high chroma colors and often have significant levels of free iron and aluminum.

Alpine Eutric Brunisols intergrade to Alpine Dystric Brunisols in areas of relatively stable slopes where snow melts by mid-July. The development of Dystric Brunisols on calcareous parent materials marks the most advanced pedogenic development in the area. The

contribution of ash to the sola however encourages acid weathering and rapid release of sesquioxides. The influence of the calcareous IIC material, which is mixed into the upper profile, is somewhat negated. The Alpine Dystric Brunisols are of dominant importance in the rolling alpine divide area. Disturbance by soil creep is still active in these areas wherever the soils occur on a slope. Columbian ground squirrels (*Citellus columbianus columbianus*) are numerous and have disturbed a considerable amount of the area. Their burrowing activity disturbs and mixes the soil horizons.

Two types of Cumulic Regosols were recognized that are very different morphologically (Plate 7) and have different origins. Cumulic Regosols (I) have developed on recent alluvial deposits where periodic deposition buries previously developed Ah horizons. Cumulic Regosols (II) have developed on steep slopes where active soil creep results in a highly-disrupted profile of a cumulic nature in which truncated and buried profiles are common.

Gleysolic soils have developed in areas of groundwater discharge and ponded snowmelt. The saturated soils display low chroma colors typical of anaerobic conditions but distinct mottles may be present in upper horizons or in permeable layers in the soil where movement of oxygenated water occurs (Plate 6).

The earth hummocks have developed in enclosed basins where ash deposits of up to 1 m in thickness occur. Snow release occurs in late July and the hummocks are covered with a dense mat of *Carex nigricans*. The occurrence and formation of such features has been studied by many workers (Bryan, 1946; Hopkins and Sigafoos,1954; Billings and Mooney, 1959; Johnson and Billings, 1962; Lundqvist, 1969).

Genesis of the earth hummocks seems to be due to horizontal and vertical displacement of material by freeze-thaw processes. A continuous plant cover seems to be necessary to hold the materials together and a high water table or possibly groundwater discharge may be involved.

Aspects of Classification

The soils were classified according to the System of Soil Classification for Canada (C.S.S.C., 1970) however problems were encountered in the application of this classification scheme.

The Brunisolic soils present several problems in classification, especially those Brunisols with high amounts of amorphous colloids in the B horizons. The B horizons of the Alpine Dystric Brunisols and of some of the Alpine Eutric Brunisols contain large amounts of oxalate-extractable iron and aluminum in comparison to the underlying IIC or IIBC horizons. In the Canadian classification scheme a B horizon in which the oxalate-extractable Fe plus Al exceeds that of the IC horizon by 0.8% or more, and the organic matter to iron ratio is less than 20, is classified as a Bf horizon and the soil is included in the Podzolic Order. The properties of the B horizons which contain volcanic ash cannot be compared to the IIC horizons which have no ash content. The high contents of amorphous sesquioxides seem to be attributable to weathering of the ash. If the 0.8% criteria were used many of the B horizons of the Brunisolic soils including some of the Bmk horizons of the Alpine Eutric Brunisols which have alkaline pH and as much as 2.4% $CaCO_3$ equivalent, could qualify as Bf horizons.

McKeague (1967) suggested that a total of 0.65% pyrophosphate-extractable iron plus aluminum is indicative of a Podzolic Bf horizon. This criteria avoids the problem of comparing different parent materials however some of the Bm horizons of the Eutric Brunisols would qualify as Bf horizons and some of the Ah horizons have values that exceed the 0.65% level.

Due to the effect of the volcanic ash and the lack of evidence for eluviation these horizons have been classified as Bm horizons and the soils have been classed in the Brunisolic Order.

Naming of the turf horizons is also somewhat of a problem. An L designation was used — meaning an organic layer characterized by an accumulation of organic matter in which the original structures are easily discernible which is developed under imperfectly to well-drained conditions (C.S.S.C., 1970). This designation is usually assigned to raw forest litter however and does not characterize the densely rooted mat of an alpine turf satisfactorily.

The two types of Cumulic Regosols recognized have very different morphology and genesis yet are not separated at the subgroup level. Those Orthic Regosols with deep, black Ah horizons are distinctly different morphologically from Orthic Regosols which lack or have very thin Ah horizons, yet are classified in the same subgroup. The classification system does not separate, at the subgroup level, soils which appear to be distinctly different in this environment. At the same time, some Alpine Dystric and Alpine Eutric Brunisols that have identical characteristics, except for reaction and base saturation of the B horizon, are separated into different subgroups.

In the System of Soil Classification for Canada (C.S.S.C., 1970)

an arbitrary depth of 10 cm has been chosen as the minimum depth of a soil. "Non-soils" with less than 10 cm depth are important in alpine areas, both in terms of areal extent and ecologically as they support the biomass of significant ecosystems but they cannot be called soils. It is strongly suggested that this criteria come under review.

Another classification problem is posed by the extremely turbated soils occurring under the earth hummock patterns. Cryoturbated soils are of considerable areal significance in the alpine and arctic areas of Canada and cannot at present be adequately classified.

SUMMARY AND CONCLUSIONS

Definite relationships between soil development, microclimate, geomorphic processes and plant communities are indicated by the results of this study of the Sunshine alpine area in the Canadian Rocky Mountains. Some examples are:

1. Alpine Dystric Brunisols are widespread on the rolling, relatively stable surfaces of the alpine divide area under *Phyllodoce glanduliflora* and *Antennaria lanata* community types.
2. Three main types of Alpine Eutric Brunisols were recognized. Type I are morphologically similar to and are geographically associated with the Alpine Dystric Brunisols. Type II occur on windswept slopes at high elevations under *Dryas hookeriana* and *D. hookeriana* - *Carex scirpoidea* community types. Type III are associated with *Kobresia myosuroides* community types on relatively snowfree ridges.
3. Two types of Orthic Regosols are of considerable areal importance. Type I Orthic Regosols, which have minimal Ah development, occur in late snowbed areas often under *Saxifraga lyallii* community types. Type II Orthic Regosols have deep Ah horizons and are found in association with the Type II Alpine Eutric Brunisols.
4. Cumulic Regosols of two types are present. Type I are poorly drained soils on recent alluvial deposits under *Salix barrattiana* and Type II occur on steep, unstable

4. (continued)

   slopes under *Anemone occidentalis* communities.

5. Orthic Gleysols, Humic Gleysols and Rego Humic Gleysols are present in poorly drained basin areas. Plant cover generally consists of sedges such as *Eriophorum* spp. and *Carex* spp.

6. Earth hummocks occur in several small basins where there are thick accumulations of volcanic ash. The soils are highly turbated and cannot be classified using the present Canadian taxanomic system. *Carex nigricans* provides a continuous vegetal mat over the hummocks.

Field observations and laboratory results show volcanic ash has a significant influence on the characteristics of most of the soils of the area. The processes of mass-wasting and frost action disrupt soil horizons and mix various parent materials together. The soil forming processes are restricted by the cool temperatures and short snowfree period.

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APPENDIX

Location:	T-1, Summit of Windy Point, 51°03'40, 115°44'35
Elevation:	7935 feet A.M.S.L.*
Slope:	30%
Aspect:	West
Drainage Class:	Rapidly drained
Parent Material:	Limestone bedrock (Devonian Palliser formation)
Vegetation:	*Dryas* - *Carex* community
Soil Classification:	Alpine Eutric Brunisol (calcareous)
Remarks:	There is considerable surface scree (flat flagging) present. Bedrock very close to surface. Arid wind-swept slope.

Horizon	Depth (cm)	
Ahk1	0-5	Dark brown (10YR 3/3 m), grayish brown (10YR 5/2 d) loam to sandy loam; weak, fine granular; very friable; abundant, fine vertical roots; very weakly effervescent; 15% coarse fragments; gradual, wavy boundary; 2 to 8 cm thick; pH 7.7.
Ahk2	5-15	Very dark brown (10YR 2/2 m), dark grayish brown (10YR 4/2 d) silt loam; weak, medium subangular blocky; very friable; abundant, fine vertical roots; very weakly effervescent; 5% coarse fragments; clear, wavy boundary; 5 to 13 cm thick; pH 7.9.
Bmk	15-40	Dark brown (10YR 3/3 m), light brownish gray (10YR 6/2 d) gravelly sandy loam; weak, medium subangular blocky; very friable; strongly effervescent; 50% coarse fragments; gradual, smooth boundary; 20 to 30 cm thick; pH 7.9.
Ck	40-60	Brown (10YR 4/3 m), pale brown (10YR 6/3 d) very gravelly sandy loam; moderate, medium subangular blocky; very friable; very few, fine vertical roots; strongly effervescent; 70% coarse fragments; pH 7.9.
R	60+	Limestone bedrock.

* A.M.S.L. Above Mean Sea Level

T-1 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g H	Na	K	Ca	Mg	SUM	TEC	Avail P ppm	Oxalate Fe %	Oxalate Al %
R70470	0-5	Ahk1	7.7	8	0.4	4.6	10	55.4	-	-	-	-	-	-	22.6	5	-	-
471	5-15	Ahk2	7.9	6	0.4	3.3	8	30.9	-	-	-	-	-	-	25.9	1	0.47	0.80
472	15-40	Bmk	7.9	1	0.1	0.6	6	76.9	-	-	-	-	-	-	6.7	0	0.20	0.20
473	40-60	Ck	7.9	-	-	-	-	89.0	-	-	-	-	-	-	2.4	1	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	Moisture Retention % 1/10 atm	15 atm	Bulk Dens g/cm^3
470	L-SL	15	50	40	10	2.4	52	20	
471	SiL	5	38	57	5	3.3	66	19	
472	SL	50	55	39	6	0.8	29	4.9	
473	SL	70	57	37	6	0.2	20	2.5	

Location:	T-2, Saddle of Quartz Hill, 51°02'15, 115°45'55
Elevation:	8200 feet A.M.S.L.
Slope:	Level
Aspect:	
Drainage Class:	Poorly drained
Parent Material:	Water-sorted colluvium
Vegetation:	*Salix nivalis* community
Soil Classification:	Rego Humic Gleysol
Remarks:	Plot is located in a depression in the saddle, where water is supplied by snow beds.

Horizon	Depth (cm)	
L	5-0	Very dark brown (10YR 2/2 m),very dark gray (10YR 3/1 d) fibrous turf; abundant, fine random and plentiful, medium horizontal roots; clear, smooth boundary; pH 6.8.
Ahg	0-33	Black (10YR 2/1 m),very dark grayish brown (10YR 3/2 d) silt loam; amorphous; friable; few, fine random roots to 35 cm; gradual, wavy boundary; 30 to 35 cm thick; pH 7.5.
Cg	33-50+	Dark brown (10YR 4/3 m), pale brown (10YR 6/3 d) very gravelly loam; fragmental; friable; moderately effervescent; pH 8.1.

T-2 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70621	5-0	L	6.8	35	1.6	20.1	13	-	4.3	tr	0.8	72.5	5.6	83.2	62.1	2	-	-
622	0-33	Ahg	7.5	15	0.7	8.8	12	1.3	-	-	-	-	-	-	50.3	1	-	-
623	33-50	Cg	8.1	-	-	-	-	19.5	-	-	-	-	-	-	6.7	15	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
621	-	-	-	-	-	7.8	120	58	-
622	SiL		26	63	11	8.3	92	30	-
623	L		39	46	15	0.7	30	7.2	-

Location:	T-3, East of Rock Isle Lake, $51^{o}03'45$, $115^{o}45'01$
Elevation:	7700 feet A.M.S.L.
Slope:	
Aspect:	West
Drainage Class:	Rapidly drained
Parent Material:	Glacial till
Vegetation:	*Phyllodoce glanduliflora* community
Soil Classification:	Alpine Eutric Brunisol
Remarks:	The Ah and Bm are composed of till that has been moved and mixed by mass wasting and ground squirrel activity. Aeolian material mixed into Ah and Bm. IIBC is till that appears to have been churned up. IIICk is more compact till that has not been disturbed.

Horizon	Depth (cm)	
L	3-0	Very dark gray to black (10YR 2.5/1 d) fibrous turf; abundant, fine random and abundant, medium horizontal roots; abrupt, smooth boundary; pH 5.4.
Ah	0-5	Very dark grayish brown (10YR 3/2 m), very dark gray (10YR 3/1 d) silt loam; weak, fine granular; very friable; plentiful, fine vertical roots; 15% coarse fragments; clear, wavy boundary; 1 to 8 cm thick; pH 5.7.
Bm	5-13	Dark brown (7.5YR 4/4 m, 10YR 4/3 d) silt loam; weak, medium granular; very friable; few, fine vertical roots; 15% coarse fragments; clear, wavy boundary; 4 to 15 cm thick; pH 7.1.
IIBC	13-30	Yellowish brown (10YR 5/6 m, 5/4 d) gravelly silt loam; moderate, fine granular; friable; very few, fine vertical roots; 40% cobbles; 10 to 20 cm thick; pH 7.5.
IIICk	30-70+	Dark brown (10YR 4/3 m), grayish brown (10YR 5/2 d) very gravelly sandy loam; very few, fine vertical roots to 40 cm; 70% coarse fragments; pH 7.8.

T-3 CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g H	Na	K	Ca	Mg	SUM	TEC	Avail P ppm	Oxalate Fe %	Oxalate Al %
R70596	3-0	L	5.4	44	1.9	25.3	14	-	20.4	tr	1.5	46.0	13.2	81.1	78.9	6	-	-
597	0-5	Ah	5.7	20	1.0	11.5	12	-	10.0	0.1	0.3	26.0	7.5	43.9	43.0	1	0.75	0.68
598	5-13	Bm	7.1	7	0.4	3.9	10	2.4	-	0.1	0.1	21.8	5.8	27.8	29.8	2	1.17	2.40
599	13-30	IIBC	7.5	2	0.1	0.9	8	0.5	-	tr	tr	10.5	4.0	14.5	11.0	1	0.75	0.44
600	30-60	IIICk	7.8	-	-	-	-	53.6	-	-	-	-	-	-	2.0	10	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm Sand 2-.05	Silt .05-.002	Clay <.002	Moisture Retention % A.D.	1/10 atm	15 atm	Bulk Dens g/cm^3
596		-	-	-	-	9.7	130	91	-
597	SiL	15	26	69	5	5.0	88	39	-
598	SiL	15	24	72	4	7.4	74	22	-
599	SiL	40	30	57	13	1.6	34	11	-
600	SL	70	61	33	6	0.1	27	25	-

Location:	T-4, W. of Twin Cairn Mtn., 51°04'15, 115°48'30
Elevation:	7900 feet A.M.S.L.
Slope:	10%
Aspect:	West
Drainage Class:	Rapidly drained
Parent Material:	Colluvium
Vegetation:	*Dryas* community
Soil Classification:	Alpine Eutric Brunisol
Remarks:	There is minimal indication of downslope soil movement (streaks of buried Ah). There is considerable surface micro-relief (3-9"). Ah is thicker under high areas. Extensive ground squirrel activity is evident.

Horizon	Depth (cm)	
Ah	0-10	Black (10YR 2/1 m), very dark gray (10YR 3/1 d) silt loam; moderate, medium granular; very friable; plentiful, fine random roots (turfy); 10% coarse fragments; clear, wavy boundary; 4 to 20 cm thick; pH 6.1.
Bm	10-15	Dark reddish brown (5YR 3/4 m), and dark brown (7.5YR 3/2 m), brown (10YR 4/3 d) silt loam; weak, fine granular; friable; plentiful, fine random roots; 10% coarse fragments; clear, smooth boundary; 3 to 8 cm thick; pH 6.5.
C	15-70+	Brown (10YR 5/3 m), pale brown (10YR 6/3 d) loam and gravelly loam; weak, medium granular; friable; 10 to 35% coarse fragments; pH 7.2.

T-4 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70491	0-10	Ah	6.1	26	1.3	15.2	12	-	7.9	tr	0.5	40.0	13.4	61.8	62.3	12	0.45	0.50
492	10-15	Bm	6.5	10	0.5	5.9	11	-	5.8	0.1	0.1	11.0	4.4	2.14	33.3	2	1.05	1.71
493	15-70	C	7.2	-	-	-	-	-	-	tr	0.1	2.4	2.2	4.8	7.4	1	0.49	0.15

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
491	-	10	-	-	-	5.8	126	73	
492	SiL	10	22	75	3	5.8	95	29	
493	SL	10-35	27	41	12	0.8	32	7.4	

Location:	T-5, South of Larix Lake, 51°02'40, 115°47'02
Elevation:	7800 feet A.M.S.L.
Slope:	35%
Aspect:	West
Drainage Class:	Rapidly drained
Parent Material:	Aeolian/Glacial till/Bedrock
Vegetation:	*Cassiope mertensiana* community
Soil Classification:	Lithic Alpine Eutric Brunisol
Remarks:	The turfy L horizon is quite tussocky and terraced with about 10 cm risers. The Bm is discontinuous due to disruptions by soil creep. Silt coatings evident on pebbles in the Bm.

Horizon	Depth (cm)	
L	10-0	Tussocky turf; clear, wavy boundary.
Ah	0-15	Very dark brown (10YR 2/2 m), very dark grayish brown (10YR 3/2 d) silt loam; weak, medium subangular blocky; very friable; plentiful, fine vertical roots; 5% coarse fragments; clear, wavy boundary; 10 to 20 cm thick; pH 6.8.
Bm	15-18	Dark brown (7.5YR 4/3 m) silt loam; weak, medium granular; friable; few, fine vertical roots; 5% coarse fragments; clear, broken boundary; 0 to 7 cm thick; pH 7.0.
C	18-40	Yellowish brown (10YR 5/4 m), pale brown (10YR 6/3 d) shaley loam; weak, coarse granular to weak, fine subangular blocky; friable; very few, fine vertical roots to bedrock at 40 cm; 50% coarse fragments; pH 7.6.
R	at 35-40	Shaley, cherty bedrock.

T-5 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70640	0-15	Ah	6.8	19	1.0	11.0	12	-	5.6	0.2	0.1	40.0	10.9	56.8	56.3	1	-	-
641	18-40	C	7.6	-	0.1	-	-	0.4	-	-	-	-	-	-	7.1	36	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
640	SiL	5	21	74	4	7.2	130	39	-
641	L	50	45	45	10	0.4	34	7.3	-

Location:	T-6, Lookout Mtn., 51°04'40, 115°46'
Elevation:	7950 feet A.M.S.L.
Slope:	30%
Aspect:	West
Drainage Class:	Rapidly drained
Parent Material:	Colluvium
Vegetation:	*Dryas* community
Soil Classification:	Orthic Regosol (calcareous)
Remarks:	Small lenses of aeolian material are included in the colluvium. The upper 20 cm appears to be very stable and is moving downslope, the 20 to 40 cm depth is slightly more compact, and below 40 cm the soil is almost firm - indicating resistance to mass wasting with depth. Thickness of the Ah is constant under and between Dryas patches, suggesting patches are migrating.

Horizon	Depth (cm)	
L	2-0	Dryas turf; 60% cover; plentiful, fine vertical and abundant, medium horizontal roots; clear, broken boundary; 0 to 4 cm thick.
Ahk1	0-5	Very dark grayish brown (10YR 3/2 m), dark grayish brown (10YR 4/2 d) gravelly silt loam; weak, fine granular; very friable; plentiful, fine vertical roots; weakly effervescent; 50% coarse fragments; gradual, broken boundary; 0 to 7 cm thick; pH 7.7.
Ahk2	5-12	Dark brown (10YR 3/3 m), grayish brown (10YR 4.5/2 d) gravelly silt loam; weak, fine granular; very friable; plentiful, fine vertical roots; weakly effervescent; 50% coarse fragments; clear, wavy boundary; 5 to 10 cm thick; pH 8.1.
Ahb	12-15	Very dark brown (10YR 2/2 m) sandy loam; clear, broken boundary; 0 to 7 cm thick (pocket).
Ck1	15-32	Brown (10YR 5/3 m), pale brown (10YR 6/3 d) very gravelly sandy loam; amorphous; loose; very few, fine vertical roots; moderately effervescent; 70% coarse fragments; diffuse, smooth boundary; pH 8.0.
Ck2	32-60	Dark grayish brown (10YR 4/2 m), grayish brown (10YR 5/2 d) very gravelly sandy loam; fragmental; friable; very few, fine vertical roots to 45 cm; moderately effervescent; 75 to 90% coarse fragments; abrupt, smooth boundary; pH 8.2.
R	60+	Bedrock

T-6 CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70574	0-5	Ahk1	7.7	8	0.5	4.6	9	26.2	-	-	-	-	-	-	29.8	3	-	-
575	5-12	Ahk2	8.1	4	0.3	2.4	9	40.3	-	-	-	-	-	-	16.0	0	-	-
576	15-32	Ck1	8.0	-	tr	-	-	91.6	-	-	-	-	-	-	2.0	<1	-	-
577	32-60	Ck2	8.2	-	tr	-	-	92.5	-	-	-	-	-	-	0.9	0	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
574	SiL	50	38	58	4	3.7	72	25	-
575	SiL	50	38	54	8	1.6	55	14	-
576	SL	70	71	23	6	0.1	17	2.0	-
577	SL	75-90	69	25	6	0.1	17	1.3	-

Location:	T-7, Lookout Mtn., 51°04'55, 115°45'01
Elevation:	8400 feet A.M.S.L.
Slope:	11%
Aspect:	Southwest
Drainage Class:	Rapidly drained
Parent Material:	Colluvium
Vegetation:	*Dryas* - *Carex* community
Soil Classification:	Orthic Regosol (calcareous)
Remarks:	Depth of Ah1 and Ah2 varies with local slope, being fairly thick at toe of a small slope. Depth to bedrock is extremely variable, resulting in both Lithic and Orthic Regosols being present.

Horizon	Depth (cm)	
L	2-0	Dryas turf; plentiful, fine vertical and abundant, medium horizontal roots; clear, smooth boundary; 1 to 3 cm thick.
Ahk1	0-5	Very dark gray (10YR 3/1 m, 3/1.5 d) gravelly silt loam; weak, fine granular; very friable; plentiful, fine random roots; moderately effervescent; 50% coarse fragments; clear, broken boundary; 0 to 15 cm thick; pH 7.9.
Ahk2	5-15	Dark brown (10YR 3/2 m), dark grayish brown (10YR 4/2 d) silt loam; weak, fine granular; very friable; few, fine vertical roots; moderately effervescent; 15% coarse fragments; abrupt, wavy boundary; 5 to 15 cm thick; pH 8.0.
IICk	15-60	Brown (10YR 5/3 m), light brownish gray (10YR 5.5/2 d) very gravelly sandy loam; single grained; loose; few, fine vertical roots to 40 cm; strongly effervescent; abrupt, irregular boundary; pH 8.0.
R	60+	Bedrock.

T-7 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail. p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70578	0-5	Ahk1	7.9	15	0.9	8.6	10	21.3	-	-	-	-	-	-	50.3	3	-	-
579	5-15	Ahk2	8.0	9	0.5	5.2	9	35.0	-	-	-	-	-	-	30.6	0	-	-
580	15-60	IICk	8.0	-	-	-	-	91.4	-	-	-	-	-	-	2.7	0	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
578	SiL	50	30	67	3	3.7	100	38	0.6
579	SiL	15	30	67	3	-	79	24	0.8
580	SL	70	60	31	9	3.3	20	3.1	-

Location:	T-8, Lookout Mtn., 51°04'40, 115°45'05
Elevation:	7540 feet A.M.S.L.
Slope:	20%
Aspect:	Southwest
Drainage Class:	Rapidly drained
Parent Material:	Colluvium/Bedrock
Vegetation:	*Vaccinium - Salix* community
Soil Classification:	Lithic Alpine Dystric Brunisol
Remarks:	Bedrock close to surface. Turf is very compact due to rooting by Vaccinium.

Horizon	Depth (cm)	
L	3-0	Very dark gray (10YR 3/1 m, 3/1 d) very compact fibrous turf; abundant, fine random and abundant, medium horizontal roots; clear, wavy boundary; 2 to 4 cm thick.
Ah	0-2	Dark brown (10YR 3/3 m, 4/3 d) silt loam; moderate, fine granular; friable; plentiful, fine random roots; 10 to 20% coarse fragments; gradual, wavy boundary; 1 to 3 cm thick; pH 5.4.
Bm	2-32	Dark yellowish brown (10YR 3/4 m, 3/4 d) loam; moderate, medium granular; friable; few, fine vertical roots; 10 to 60% coarse fragments; clear, wavy boundary; pH 6.0.
IIBC	32-42	Very dark grayish brown (10YR 3/2 m), grayish brown (10YR 5/2 d) very cobbly sandy loam; moderate, fine granular, friable; few, fine vertical roots to 50 cm or bedrock; very weakly effervescent; 60% cobble-sized fragments; abrupt, broken boundary; 0 to 20 cm thick; pH 7.3.
R	42+	Bedrock.

T-8 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70585	0-2	Ah	5.4	39	1.6	22.9	14	-	17.1	0.1	2.7	38.8	7.2	65.9	76.9	43	0.37	0.17
586	2-32	Bm	6.0	9	0.4	5.2	13	-	9.7	0.1	0.1	2.0	0.7	12.6	25.6	1	1.06	0.99
587	32-42	BC	7.3	2	0.1	1.1	9	25.7	-	tr	0.1	7.8	3.8	11.7	8.3	2	0.39	0.22

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
585	-	10-20	-	-	-	5.6	110	81	-
586	SiL	60	25	65	10	4.1	63	18	0.7
587	SL	60	50	41	9	0.6	42	20	-

Location:	T-9, S. of Lookout Mtn., 51°03'45, 115°45'01
Elevation:	7700 feet A.M.S.L.
Slope:	8%
Aspect:	Southwest
Drainage Class:	Well drained
Parent Material:	Aeolian/till/bedrock
Vegetation:	*Antennaria* community
Soil Classification:	Lithic Alpine Dystric Brunisol
Remarks:	This profile is representative of the gently sloping, well drained alpine area. Bedrock is close to surface, thus limiting rooting depth.

Horizon	Depth (cm)	
L	3-0	Dark Gray (10YR 4/1 d) fibrous turf; abundant; fine random roots; clear, wavy boundary; 2 to 6 cm thick; pH 4.9.
Ah	0-1	Dark brown (10YR 3/3 m) silt loam.
Bm	1-6	Strong brown (7.5YR 5/6 m), yellowish brown (10YR 5/4 d) silt loam; weak, fine granular; very friable; abundant; fine random roots; clear, wavy boundary; 3 to 10 cm thick; pH 5.6.
BC	6-7	Light yellowish brown (10YR 6/4 d) gravelly sandy loam; moderate, fine granular; friable; few, fine vertical roots; 50% coarse fragments; gradual, broken boundary; 0 to 2 cm thick.
IIBC	7-40	Very dark grayish brown (10YR 3/2 m), grayish brown (10YR 5/2 d) gravelly loam; moderate, medium granular; friable; plentiful, fine random roots; weakly effervescent; abrupt, wavy boundary; 20 to 40 cm thick; pH 7.6.
R	40+	Bedrock.

T-9 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70601	0-1	Ah	4.9	23	0.8	13.5	17	-	18.4	0.1	0.4	1.5	0.3	20.7	34.0	5	0.71	0.63
602	1-6	Bm	5.6	14	0.6	8.1	12	-	20.8	0.1	0.1	0.6	0.1	21.6	45.8	4	1.30	4.60
603	7-40	IIBC	7.6	1	0.1	0.6	6	26.0	-	-	-	-	-	-	5.7	30	0.85	0.16

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
601	L	-	45	45	10	3.3	92	46	-
602	SiL	-	32	65	3	7.8	98	33	-
603	L	-	49	40	11	0.5	38	6.0	-

Location:	T-10, W. of water reservoir, 51°04'25, 115°47'20
Elevation:	7380 feet A.M.S.L.
Slope:	7%
Aspect:	East
Drainage Class:	Poorly drained
Parent Material:	Alluvium/Glacial till
Vegetation:	*Salix barrattiana* community
Soil Classification:	Alpine Eutric Brunisol
Remarks:	Water table is at about 4 feet. The area the plot is located in seems to have been built up by alluvial deposition. Water now drains around this built-up area.

Horizon	Depth (cm)	
L-F	5-0	Moss litter and roots (slightly decomposed); abrupt, smooth boundary; 2 to 8 cm thick.
Ah	0-12	Black (10YR 2/1.5 m), very dark gray (10YR 3/1 d) silt loam; moderate, fine granular; friable; plentiful, fine random roots; clear, wavy boundary; 8 to 20 cm thick; pH 6.8.
Bm	12-15	Reddish brown (5YR 4/4 m), light reddish brown (5YR 6/3 d) silt loam; moderate, fine granular; very friable; few, fine vertical roots; clear, broken boundary; 0 to 6 cm thick.
IIC	15-40	Yellowish brown (10YR 5/4 m), pale brown (10YR 6/3 d) silt loam; fragmental; friable to firm; very few, fine vertical roots; 15% coarse fragments; diffuse, smooth boundary; pH 7.1.
IICk	40-70+	Yellowish brown (10YR 5/4 m), pale brown (10YR 6/3 d) gravelly loam; fragmental; firm, very few, fine vertical roots to 40 cm; 25% coarse fragments; moderately effervescent; pH 7.6.

T-10 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70568	0-12	Ah	6.8	25	1.4	14.7	11	-	4.0	0.1	0.2	51.5	10.4	66.2	67.4	5	-	-
569	15-40	IIC	7.1	-	-	-	-	0.9	-	tr	0.1	4.3	1.7	6.1	7.2	0	-	-
570	40-70	IICk	7.6	-	-	-	-	13.0	-	-	-	-	-	-	4.6	0	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
568	SiL	-	26	66	8	8.8	98	70	-
569	SiL	15	34	52	14	0.8	36	8.1	-
570	L	25	47	42	11	0.5	27	5.5	-

Location:	T-11, East slope of Wa-Wa Ridge, 51°05'25, 115°47'40
Elevation:	7700 feet A.M.S.L.
Slope:	20%
Aspect:	East-southeast
Drainage Class:	Rapidly drained
Parent Material:	Colluvium/Glacial till
Vegetation:	*Phyllodoce glanduliflora* community
Soil Classification:	Alpine Dystric Brunisol
Remarks:	The Bm1 is discontinuous and contains lenses of Ah material, indicating downslope soil creep is active. August temperature at 50 cm - 48°F (8.9°C).

Horizon	Depth (cm)	
L	1-0	Turf.
Ah1	0-8	Very dark grayish brown (10YR 3/2 m), dark grayish brown (10YR 4/2 d) shaley sandy loam; weak, fine granular; very friable; plentiful, fine random roots; 50% coarse fragments; clear, wavy boundary; 5 to 12 cm thick; pH 4.8.
Ah2	8-15	Very dark grayish brown (10YR 3/2 m), grayish brown (10YR 5/2 d) sandy loam; weak, fine granular; very friable; few, fine random roots; 10% coarse fragments; abrupt, wavy boundary; 3 to 10 cm thick; pH 5.1.
Bm1	15-18	Dark brown (7.5YR 4/4 m) silt loam; weak, fine granular; friable; very few, fine random roots; abrupt, wavy boundary; 0 to 5 cm thick.
IIBm	18-26	Dark yellowish brown (10YR 4/4 m), pale brown (10YR 6/3 d) silt loam; moderate, medium subangular blocky; friable; very few, fine random roots; 10% coarse fragments; clear, wavy boundary; 7 to 12 cm thick; pH 5.5.
IIBC	26-34	Dark grayish brown (2.5Y 4/2 m) clay loam; moderate, medium subangular blocky; friable; no roots; 15% coarse fragments; gradual, wavy boundary; 2 to 10 cm thick.
IIC	34-70+	Dark grayish brown (2.5Y 4/2 m), light brownish gray (2.5Y 6/2 d) silt loam; fragmental; firm; pH 5.2.

T-11 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70533	0-8	Ah1	4.8	13	0.5	7.6	16	-	12.6	0.2	0.4	1.2	0.8	15.2	19.0	5	-	-
534	8-15	Ah2	5.1	6	0.2	3.4	16	-	9.7	0.1	0.1	0	0.3	10.2	15.2	2	0.47	0.34
535	18-26	IIBm	5.5	1	0.1	0.4	6	-	5.8	0.1	tr	1.5	1.1	8.5	12.7	0	0.73	0.20
536	34-70	IIC	5.3	-	-	-	-	-	2.9	0.1	0.1	3.5	2.0	8.6	10.3	1	0.33	0.11

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
533	SL	50	69	26	5	2.2	45	45	0.9
534	SL	10	59	35	6	3.5	33	11	1.0
535	SiL	10	28	71	6	1.5	32	11	1.2
536	SiL	-	23	63	14	0.6	32	10	-

Location:	T-12, SE flank of Wa-Wa, 51°05'23, 115°47'15
Elevation:	7400 feet A.M.S.L.
Slope:	Less than 1%
Aspect:	
Drainage Class:	Poorly drained
Parent Material:	Alluvium
Vegetation:	*Salix barrattiana* community
Soil Classification:	Cumulic Regosol (I)
Remarks:	The alluvial material has built up the center of the basin higher than the edges where water runs. Salix grows on higher area.

Horizon	Depth (cm)	
L	3-0	Turfy; clear, smooth boundary.
Ah1	0-2	Black (10YR 2/1 m) silt loam; weak, fine granular; very friable; plentiful, fine random roots; clear, smooth boundary; 1 to 3 cm thick.
Ah2	2-19	Very dark grayish brown (10YR 3/2 m), dark grayish brown (10YR 4/2 d) loam; weak, medium granular; very friable; few, fine vertical and abundant, medium random roots; clear, smooth boundary; pH 6.1.
AC	19-32	Dark brown (10YR 3/3 m), grayish brown (10YR 5/2 d) silt loam; weak, medium granular; friable; few, fine vertical roots; clear, smooth boundary; pH 6.3.
Ah3	32-44	Very dark grayish brown (10YR 3/2 m), grayish brown (10YR 5/2 d) sandy loam; weak, medium granular; friable; very few, fine random roots; 10% coarse fragments; gradual, smooth boundary; pH 6.5.
C	44-57+	Dark brown (10YR 3/3 m) very gravelly loam; amorphous; loose; 90% gravel size fragments.

T-12 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70525	2-19	Ah2	6.1	16	0.8	9.0	11	-	6.9	tr	0.1	37.9	4.1	49.0	46.7	5	-	-
526	19-32	AC	6.3	3	0.5	1.8	4	-	4.7	0.1	0.1	21.5	2.4	28.8	27.7	-	-	-
527	32-44	Ah3	6.5	8	0.5	4.4	9	-	3.8	tr	0.1	17.8	1.7	23.4	24.3	-	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
525	L		22	67	11	5.6	94	44	-
526	SiL		25	65	10	3.1	77	23	-
527	SL	10	44	48	8	2.8	56	22	-

Location:	T-13, West of Quartz Hill, $51^{\circ}02'20$, $115^{\circ}47'10$
Elevation:	7750 feet A.M.S.L.
Slope:	20%
Aspect:	South-southeast
Drainage Class:	Rapidly drained
Parent Material:	Aeolian/Glacial till
Vegetation:	*Phyllodoce glanduliflora* community
Soil Classification:	Alpine Dystric Brunisol
Remarks:	There is some mixing of surface horizons due to colluvial action. The Ah is very light in color.

Horizon	Depth (cm)	
L	7-0	Dark yellowish brown (10YR 4/4 d) fibrous turf; abundant, fine random and abundant, medium horizontal roots; 5 to 10 cm thick; clear, wavy boundary; pH 5.6.
Ah	0-4	Dark brown (10YR 4/3 d) silt loam; weak, fine granular; very friable; few, fine random roots; clear, wavy boundary; 2 to 6 cm thick; pH 5.4.
Bm1	4-16	Strong brown (7.5YR 5/6 m), yellowish brown (10YR 5/4 d) silt loam; weak, medium platy; very friable; very few, fine vertical roots; clear, wavy boundary; 10 to 17 cm thick; pH 6.6.
IIBm2	16-19	Dark brown (7.5YR 4/4 m) silt loam; moderate, medium platy to moderate, medium subangular blocky; few, fine vertical roots; clear, broken boundary; 0 to 7 cm thick.
IIC	19-60	Yellowish brown (10YR 5/4 m), light yellowish brown (10YR 6/4 d) gravelly silt loam; moderate, medium subangular blocky; firm to friable; few, fine vertical roots to 30 cm; 40% shale fragments; abrupt, irregular boundary; pH 6.7.
R	60+	Shale bedrock occurring at 60 to 100 cm.

T-13 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70636	7-0	L	5.6	25	1.0	14.7	15	-	13.1	0.1	1.3	27.5	5.2	47.2	45.0	3	-	-
637	0-4	Ah	5.4	8	0.3	4.8	14	-	8.0	0.1	0.2	5.5	0.9	14.7	20.7	1	0.88	0.23
638	4-16	Bm1	6.6	6	0.3	3.7	11	-	6.1	0.1	0.2	8.2	2.2	16.8	25.4	1	1.15	2.18
639	19-60	IIC	6.7	-	-	-	-	-	1.2	tr	0.1	7.5	3.4	12.2	9.4	2	0.39	0.09

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
636	-	-	-	-	-	5.0	82	44	-
637	SiL	-	31	56	13	2.7	45	18	-
638	SiL	-	22	70	8	6.3	69	20	-
639	SiL	40	26	55	19	0.6	35	10	-

Location:	T-14, South of Larix Lake, $51^{\circ}02'50$, $115^{\circ}47'$
Elevation:	7600 feet A.M.S.L.
Slope:	1-3%
Aspect:	Southwest
Drainage Class:	Poorly drained
Parent Material:	Alluvium/Glacial till/Bedrock
Vegetation:	*Salix barrattiana* community
Soil Classification:	Alpine Eutric Brunisol
Remarks:	The reddish Bm is probably due to water movement above the compact till. Alternate pit showed buried Ah horizons and water table at 40 cm. Plot is located in a snowmelt drain.

Horizon	Depth (cm)	
L	8-0	Dark Brown (7.5YR 3/2 m), very dark gray (10YR 3/1 d) fibrous turf; abundant, fine random and abundant, medium horizontal roots; clear, wavy boundary; 5 to 10 cm thick; pH 6.8.
Ah	0-20	Very dark grayish brown (10YR 3/2 m), dark grayish brown (10YR 4/2 d) silt loam; few, fine vertical roots; abrupt, wavy boundary; 18 to 24 cm thick; pH 7.1.
Bm	20-25	Strong brown (7.5YR 5/8 m), yellowish brown (10YR 5/4 d) silt loam; very few, fine vertical roots; abrupt; wavy boundary; 4 to 8 cm thick; pH 7.3.
IICg1	25-28	Very dark grayish brown (2.5Y 3/2 m) silt loam; very few, fine vertical roots; clear, broken boundary; 0 to 4 cm thick.
IICg2	28-62	Light olive brown (2.5Y 5/4 m), pale yellow (2.5Y 7/4 d) silt loam; common, fine, prominent strong brown (7.5YR 5/6) mottles; very few, fine vertical roots to 45 cm; very weakly effervescent; pH 7.6.
R	62+	Bedrock.

T-14 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g H	Na	K	Ca	Mg	SUM	TEC	Avail p ppm	Oxalate Fe %	Oxalate Al %
R70642	8-0	L	6.8	43	2.3	24.9	11	-	13.4	0.1	2.2	100.0	9.2	124.9	110.1	3	-	-
643	0-20	Ah	7.1	13	0.6	7.6	12	0.3	-	0.1	0.1	33.0	2.5	35.0	39.0	1	0.78	0.68
644	20-25	Bm	7.3	7	0.5	3.9	7	0.8	-	0.1	0.1	29.5	1.8	31.5	41.3	1	1.16	4.00
645	28-62	IICg2	7.6	-	-	-	-	tr	-	-	-	-	-	-	8.2	11	0.42	0.16

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm Sand 2-.05	Silt .05-.002	Clay <.002	Moisture Retention % A.D.	1/10 atm	15 atm	Bulk Dens g/cm^3
642			-	-	-	9.2	180	100	-
643	SiL		10	76	14	4.9	70	28	-
644	SiL		26	67	7	7.8	79	28	-
645	SiL		24	53	23	0.9	37	10	-

Location:	T-15, N. side of Wa-Wa Ridge, 51°05'59, 115°47'45
Elevation:	7650 feet A.M.S.L.
Slope:	15%
Aspect:	North
Drainage Class:	Rapidly drained
Parent Material:	Colluvium (derived from shales)
Vegetation:	*Cassiope*
Soil Classification:	Alpine Dystric Brunisol
Remarks:	Plot is located on fairly unstable colluvial slope, downslope from loose shale flagging. Profile shows burying by downslope soil creep.

Horizon	Depth (cm)	
L	5-0	Fibrous turf; 0 to 8 cm thick.
Ah1	0-10	Dark brown (10YR 3/3 m), grayish brown (10YR 5/2 d) silt loam; moderate, fine subangular blocky; very friable; plentiful, fine random roots; 3 to 15 cm thick; pH 4.8.
Bm1(ash)	10-17	Yellowish red (5YR 5/6 m), yellowish brown (10YR 5/4 d) silt loam; weak, coarse platy; very friable; few, fine random roots; 0 to 8 cm thick; pH 5.7.
Ae (ash)	17-19	Brown (10YR 4.5/3 m) silt loam; 0 to 3 cm thick.
Ah2	19-22	Silt loam; 0 to 6 cm thick.
Bm2	22-25	Silt loam; 0 to 5 cm thick.
IIC	25+	Dark yellowish brown (10YR 4/4 m), light yellowish brown (10YR 6/4 d) shaley loamy sand; amorphous; loose; no roots; pH 5.2.

T-15 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70488	0-10	Ah1	4.8	13	0.6	7.6	12	-	11.6	tr	0.2	2.3	0.5	14.6	24.5	6	0.74	0.72
489	10-17	Bm1	5.7	10	0.4	6.1	14	-	11.3	0.2	0.1	1.0	2.0	14.6	32.9	2	1.85	3.00
490	25-40	IIC	5.2	-	-	-	-	-	5.2	tr	0.1	0	0.3	5.6	7.1	2	0.26	0.18

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
488	SiL		44	53	3	3.4	74	20	
489	SiL		20	47	13	4.4	104	22	
490	LS		75	20	5	1.0	-	6.9	

Location:	T-16, N. side of Wa-Wa Ridge, 51°05'45, 115°47'15
Elevation:	7650 feet A.M.S.L.
Slope:	15%
Aspect:	North-northeast
Drainage Class:	Rapidly drained
Parent Material:	Colluvium (with aeolian lenses)
Vegetation:	*Cassiope* community
Soil Classification:	Alpine Dystric Brunisol
Remarks:	The Ae and Bf occur in a lens-shaped ash deposit. Iron staining evident on rock surfaces in the Bm horizon. Slope is fairly unstable. Colluvium derived from acid shales and conglomerates.

Horizon	Depth (cm)	
Ah	0-10	Black (10YR 2/1 m), very dark gray (10YR 3/1 d) silt loam; weak, fine granular; very friable; few, fine random roots; 5% coarse fragments; clear, wavy boundary; 5 to 13 cm thick; pH 5.4.
Aej	10-11	Brown (7.5YR 4/4 m) silt loam; clear, broken boundary; 0 to 1 cm thick.
Bm1	11-16	Yellowish red (5YR 4/6 m), brown (10YR 5/3 d) silt loam; weak, very fine granular; very friable; few, fine random roots; 5% coarse fragments; clear, broken boundary; 0 to 8 cm thick; pH 5.7.
Bm2	16-20	Brown (10YR 4/3 m), pale brown (10YR 6/3 d) gravelly sandy loam; weak, fine granular; friable; few, fine random roots; 30% coarse fragments; clear, irregular boundary; 3 to 15 cm thick; pH 5.6.
C1	20-25	Brown (10YR 5/3 m), pale brown (10YR 6/3 d) gravelly sandy loam; weak, fine granular; friable; very few, fine vertical roots; 30% coarse fragments; clear, wavy boundary; 5 to 15 cm thick; pH 5.4.
C2	25-50+	Yellowish brown (10YR 5/4 m) very cobbly sandy loam; 90% coarse fragments.

T-16 CHEMICAL

Sample Number	Depth (cm)	Horizon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70484	0-10	Ah	5.4	15	0.7	8.6	12	-	11.7	tr	0.5	12.0	1.4	25.6	32.8	8	0.59	0.26
485	11-16	Bm1	5.7	9	0.7	5.2	8	-	8.8	0.2	0.2	3.5	1.2	13.9	26.4	4	1.56	1.70
486	16-20	Bm2	5.6	1	0.4	0.5	1	-	3.0	tr	tr	3.5	0.7	7.2	7.3	1	0.21	0.16
487	20-25	C1	5.4	-	-	-	-	-	2.9	tr	tr	3.0	0.6	6.5	7.9	1	0.17	0.06

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
484		5	-	-	-	2.5	72	34	
485		5	-	-	-	4.2	-	-	
486	SL	30	69	26	5	0.8	15	4.8	
487	SiL	30	37	51	12	0.9	24	6.0	

Location:	T-17, S. of Lookout Mtn., 51°03'45. 115°45'01
Elevation:	7730 feet A.M.S.L.
Slope:	6%
Aspect:	West
Drainage Class:	Moderately well drained
Parent Material:	Aeolian and colluvium/till/bedrock
Vegetation:	*Carex* community
Soil Classification:	Alpine Dystric Brunisol
Remarks:	Plot located in a poorly defined drainage channel. Turf (L) very difficult to separate from the Ah. The soil is typical of a large part of the area.

Horizon	Depth (cm)	
L	4-0	Brown (10YR 4/3 d) fibrous turf; abundant, fine random roots; clear, wavy boundary; 3 to 5 cm thick; pH 5.4.
Ah	0-3	Grayish brown (10YR 5/2 d) silt loam; weak, fine granular; very friable; abundant, fine random roots; clear, broken boundary; 0 to 7 cm thick; pH 5.3.
Bm	3-20	Yellowish brown (10YR 5/6 m)and strong brown (7.5YR 5/6 m) and light yellowish brown (10YR 6/4 d) silt loam; weak, fine granular; very friable; plentiful, fine vertical roots; clear, wavy boundary; 12 to 20 cm thick; pH 5.8.
IIBC	20-40	Dark brown (10YR 3/3 m), grayish brown (10YR 5/2 d) gravelly silt loam; moderate, fine granular; friable; plentiful, fine vertical roots; gradual, smooth boundary; pH 6.8.
IICk	40-70	Dark brown (10YR 4/3 m), light brownish gray (10YR 6/2 d) gravelly sandy loam; moderate, medium sub-angular blocky; friable; few, fine vertical roots to bedrock; pH 7.8.
R	70+	Bedrock.

T-17 CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g H	Na	K	Ca	Mg	SUM	TEC	Avail p ppm	Oxalate Fe %	Oxalate Al %
R70604	4-0	L	5.4	21	0.9	12.0	13	-	16.6	0.1	1.8	3.0	2.0	23.5	32.4	15	-	-
605	0-3	Ah	5.3	17	0.7	10.1	15	-	13.8	0.1	0.4	1.4	0.4	16.1	22.9	4	0.52	0.68
606	3-20	Bm	5.8	6	0.3	3.3	12	-	7.8	tr	0.1	0.8	0.1	8.8	5.4	10	0.60	2.00
607	20-40	IIBC	6.8	1	0.1	0.7	10	-	1.3	tr	tr	3.0	2.3	6.6	3.0	6	0.25	0.26
608	40-70	IICk	7.8	-	-	-	-	36.5	-	-	-	-	-	-	-	16	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm Sand 2-.05	Silt .05-.002	Clay <.002	Moisture Retention % A.D.	1/10 atm	15 atm	Bulk Dens g/cm^3
604			-	-	-	4.3	-	-	0.6
605	SiL		23	72	5	3.7	120	28	-
606	SiL		20	67	13	3.3	79	15	0.8
607	SiL		43	48	9	0.6	32	6.1	-
608	SL		53	39	8	0.2	31	4.4	-

Location:	T-18, Eagle Mtn., 51°06'10, 115°45'42
Elevation:	8150 feet A.M.S.L.
Slope:	20%
Aspect:	West-southwest
Drainage Class:	Rapidly drained
Parent Material:	Colluvium and aeolian/bedrock at 40 cm.
Vegetation:	*Dryas* community
Soil Classification:	Lithic Alpine Eutric Brunisol (calcareous)
Remarks:	Stony surface, slight Dryas-terrace micro-relief. Ash lenses present in Ah and Bm. Mass wasting more evident in alternate pit, with buried horizons being present.

Horizon	Depth (cm)	
L	5-0	Very dark grayish brown (10YR 3/2 m), very dark gray (10YR 3/1 d) fibrous turf and loose leaf litter; abundant, fine random roots; 5% coarse fragments; clear, wavy boundary; 2 to 7 cm thick; pH 7.4.
Ah	0-5	Dark yellowish brown (10YR 3/4 m), dark brown (10YR 3/3 d) silt loam; weak, fine granular; soft; few, fine random roots; gradual, wavy boundary; 3 to 9 cm thick; pH 7.6.
Bmk	5-7	Dark brown (10YR 3/3 m) sandy loam; weak, fine granular; very friable; very few, fine vertical roots; weakly effervescent; gradual, broken boundary; 0 to 5 cm thick; pH 8.0.
Ck	7-40	Dark yellowish brown (10YR 4/4 m), brown (10YR 5.5/3 d) gravelly loam; fragmental; friable; very few, fine vertical roots to bedrock; strongly effervescent; 40% coarse fragments; pH 8.0.
R	40+	Bedrock.

<u>Alternate Pit</u>

L	2-0
Ah	0-3
Bmk	3-7
Ck	7-12
Ahb & Bmb	12-24 (R70665)
C	

T-18 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70662	5-0	L	7.4	26	1.4	15.0	11	0.7	-	0.6	0.6	90.0	15.0	106.2	74.4	8	-	-
663	0-5	Ah	7.6	10	0.6	6.0	10	6.8	-	-	-	-	-	-	22.0	0	-	-
664	7-40	Ck	8.0	-	0.1	-	-	40.7	-	-	-	-	-	-	6.7	0	-	-
665	12-24	Ahb+ Bmb	8.2	-	0.3	-	-	12.9	-	-	-	-	-	-	38.6	0	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
662		5	-	-	-	6.4	95	60	-
663	SiL	-	33	59	8	4.8	75	27	-
664	L	40	41	46	13	0.7	27	48	-
665	SiL-SL	-	43	52	5	2.4	58	12	-

Location:	T-19, Eagle Mtn., $51^{o}05'50$, $115^{o}45'40$
Elevation:	8100 feet A.M.S.L.
Slope:	35-40%
Aspect:	South-southwest
Drainage Class:	Rapidly drained
Parent Material:	Colluvium + Aeolian/Bedrock
Vegetation:	*Carex - Dryas* community
Soil Classification:	Lithic Alpine Eutric Brunisol (calcareous)
Remarks:	The Ah and Bm horizons are largely aeolian material. Profile has been truncated by colluvial material moving over top of profile.

Horizon	Depth (cm)	
L	4-0	Very dark grayish brown (10YR 3/2 m), very dark gray (10YR 3/1 d) fibrous turf; abundant, fine random roots; clear, wavy boundary; 2 to 7 cm thick; pH 7.7.
Ahk	0-2	Very dark brown (10YR 2/2 m), very dark gray (10YR 3/1 d) silt loam; weak, fine granular, very friable; plentiful, fine vertical roots; less than 5% coarse fragments; moderately effervescent; gradual, broken boundary; 0 to 5 cm thick; pH 7.9.
Bmk	2-10	Dark brown (10YR 3/3 m), dark grayish brown (10YR 4/2 d) silt loam; weak, fine granular; very friable; few, fine vertical roots; moderately effervescent; clear, wavy boundary; 3 to 9 cm thick; pH 8.0.
Ck	10-40	Yellowish brown (10YR 5/4 m), pale brown (10YR 6.5/3 d) gravelly sandy loam; fragmental; very friable; few, fine vertical roots to 30 cm; strongly effervescent; 50% coarse fragments; pH 8.0.
R	40+	Limestone bedrock.

T-19 CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70666	4-0	L	7.7	-	1.5	-	-	1.5	-	-	-	-	-	-	71.6	3	-	-
667	0-2	Ahk	7.9	26	1.5	14.4	10	4.6	-	-	-	-	-	-	66.7	1	0.68	0.87
668	2-10	Bmk	8.0	10	0.6	5.6	9	22.1	-	-	-	-	-	-	28.0	2	0.68	0.75
669	10-40	Ck	8.0	-	-	-	-	-	-	-	-	-	-	-	2.1	10	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
666			-	-	-	6.8	110	56	-
667	SiL	5	28	71	1	6.9	130	56	-
668	SiL	-	29	67	4	3.9	82	24	-
669	SL	50	55	35	10	0.2	18	25	-

Location:	T-20, W. of Sunshine Reservoir, 51°04'25, 115°47'30
Elevation:	7475 feet A.M.S.L.
Slope:	25%
Aspect:	Northeast
Drainage Class:	Rapidly drained
Parent Material:	Colluvium
Vegetation:	*Saxifraga lyallii* community
Soil Classification:	Alpine Eutric Brunisol
Remarks:	Plot located in drainage channel. Probably a late snowbed area. Weak terracing of the slope is indicative of some downslope soil movement. The A and B horizons are very similar.

Horizon	Depth (cm)	
L	5-0	Fibrous turf; abundant, fine random and abundant, medium horizontal roots; abrupt, wavy boundary.
Ah	0-10	Dark brown (10YR 3/3 m), grayish brown (10YR 5/2 d) sandy loam; moderate, fine granular; very friable; plentiful, fine random roots; 15% coarse fragments; gradual, smooth boundary; 6 to 15 cm thick; pH 7.1.
Bm	10-30	Very dark grayish brown (10YR 3/2 m), grayish brown (10YR 5/2 d) shaley sandy loam; moderate, medium subangular blocky; friable; few, fine vertical roots; 40% coarse fragments; gradual, smooth boundary; 15 to 25 cm thick; pH 7.2.
C	30-60+	Dark yellowish brown (10YR 4/4 m), pale brown (10YR 6/3 d) shaley sandy loam; moderate, medium subangular blocky; firm; few, fine vertical roots to 40 cm; 30% coarse fragments; pH 7.3.

T-20 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70565	0-10	Ah	7.1	4	0.2	2.4	10	0.9	-	tr	0.1	12.5	2.2	14.8	16.3	8	0.87	0.42
566	10-30	Bm	7.2	4	0.2	2.1	11	0.7	-	tr	0.1	10.8	1.8	12.7	14.3	8	0.84	0.41
567	30-60	C	7.3	-	0.1	-	-	0.6	-	tr	0.1	3.5	1.2	4.8	7.1	5	0.64	0.11

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
565	SL	15	50	44	6	1.7	43	15	-
566	SL	40	51	41	8	1.2	42	12	-
567	SL	30	46	46	8	0.2	35	7.2	-

Location:	T-21, Standish Hump, 51°04'35, 115°47'10
Elevation:	7500 feet A.M.S.L.
Slope:	65%
Aspect:	East
Drainage Class:	Rapidly drained
Parent Material:	Colluvium
Vegetation:	*Anemone occidentalis* community
Soil Classification:	Cumulic Regosol (II)
Remarks:	This is an unstable colluvial slope having continual downslope movement, mostly by soil creep. Profile shows buried horizons and weak horizon differentiation.

Horizon	Depth (cm)	
L	5-0	Fibrous turf; clear, wavy boundary.
Ah	0-8	Dark brown (10YR 3/3 m), grayish brown (10YR 4.5/2 d) silt loam; moderate, fine granular; friable; abundant, fine vertical and abundant, medium random roots; 5% coarse fragments; diffuse, wavy boundary; 2 to 10 cm thick; pH 5.4.
AC	8-20	Dark brown (10YR 3/3 m), grayish brown (10YR 4/2.5 d) silt loam; moderate, fine granular; very friable; plentiful, fine vertical roots; 5 to 10% coarse fragments; abrupt, wavy boundary; 10 to 15 cm thick; pH 5.6.
Ahb	20-21	Dark brown (7.5YR 3/2 m) silt loam; moderate, fine granular; very friable; clear, broken boundary; 0 to 1 cm thick.
Bmb	21-26	Strong brown (7.5YR 4/6 m) silt loam; moderate, fine granular; very friable; clear, broken boundary; 0 to 8 cm thick.
C	26-90+	Yellowish brown (10YR 5/4 m), pale brown (10YR 5.5/3 d) loam; moderate, coarse subangular blocky; friable; 60% cobbles; pH 7.2.

T-21 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70571	0-8	Ah	5.4	9	0.4	5.2	11	-	12.6	0.1	0.4	0	0.5	13.6	26.5	5	1.12	0.66
572	8-20	AC	5.6	7	0.3	4.1	12	-	9.2	tr	tr	0.6	0.4	10.2	21.0	4	1.10	0.87
573	26-90	C	7.2	-	-	-	-	1.3	-	tr	tr	4.6	2.1	6.7	7.6	1	0.72	0.13

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
571	SiL	5	40	52	8	4.0	56	26	-
572	SiL	5-10	41	50	9	3.4	53	21	-
573	SiL	60	43	47	10	0.4	42	6.0	-

Location:	T-22, N. of Lookout Mtn., $51^{\circ}05'10$, $115^{\circ}45'01$
Elevation:	7360 feet A.M.S.L.
Slope:	Level
Aspect:	
Drainage Class:	Poorly drained
Parent Material:	Alluvium
Vegetation:	*Salix barrattiana* community
Soil Classification:	Cumulic Regosol (I)
Remarks:	Plot is located in a meltwater drainage channel. Periodic alluvial deposition evident in profile, with only one weak discontinuous Ahb at 25 cm (very little time between deposits).

Horizon	Depth (cm)	
L	5-0	Very dark gray (10YR 3/1 d) loose turf with undecomposed leaf litter; clear, wavy boundary; 3 to 6 cm thick; pH 7.2.
Ah & C	0-8	Very dark brown (10YR 2/2 m) and very dark grayish brown (10YR 3/2 m), very dark gray (10YR 3/1 d) crushed color, silt loam; amorphous to weak, fine granular; very friable; few, fine random and plentiful, medium horizontal roots; abrupt, wavy boundary; 7 to 12 cm thick; pH 7.5.
Ck1	8-18	Dark brown (10YR 4/3 m), grayish brown (10YR 5/2 d) loam; weak, fine subangular blocky; friable; few, fine horizontal roots, smooth, wavy boundary; 8 to 15 cm thick; pH 7.7.
Ck2	18-30	Very dark grayish brown (10YR 3/2 m) silt loam; amorphous, friable to firm; very few, fine horizontal roots; very weakly effervescent; gradual, wavy boundary; pH 7.7.
Ck3	30-48	Dark yellowish brown (10YR 4/4 m), brown (10YR 5/3 d) silt loam; amorphous; friable; very few, fine horizontal roots; many vesicular pores, very weakly effervescent; clear, smooth boundary; pH 7.5.

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T-22 (continued)

Horizon	Depth (cm)	
Ck4	48+	Yellowish brown (10YR 5/4 m), very pale brown (10YR 6.5/3 d) silt loam; amorphous; firm; very few, fine horizontal roots to 55 cm; few, vesicular pores; strongly effervescent; pH 7.9.

T-22 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70656	5-0	L	7.2	23	1.5	13.4	9	3.1	-	0	0.6	58.5	8.2	67.3	63.2	23	-	-
657	0-8	Ah+C	7.5	17	0.9	10.1	12	23.6	-	-	-	-	-	-	61.6	4	-	-
658	8-18	Ck1	7.7	-	-	-	-	51.9	-	-	-	-	-	-	17.4	1	-	-
660	30-48	Ck3	7.5	-	-	-	-	0.8	-	-	-	-	-	-	37.0	3	-	-
661	48-70	Ck4	7.9	-	-	-	-	48.8	-	-	-	-	-	-	3.2	0	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
656			-	-	-	4.4	130	65	-
657	SiL		16	59	25	8.3	96	52	-
658	L		37	46	17	1.8	43	14	-
660	SiL		15	74	11	6.5	95	24	-
661	SiL		20	67	13	0.3	28	3.7	-

Location: T-23, S. of Sunshine Village

Elevation: 7600 feet A.M.S.L.

Slope: Depressional Area

Aspect:

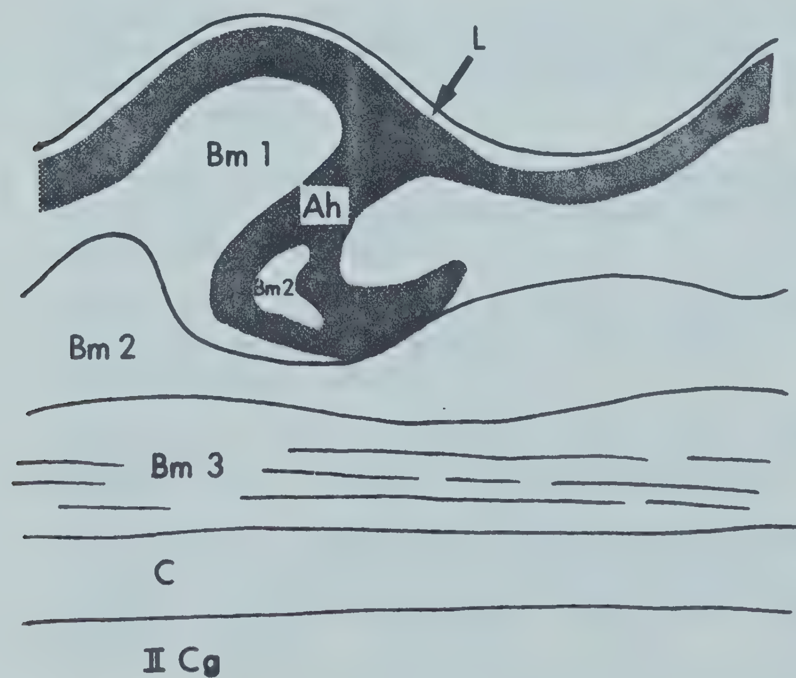
Drainage Class: Imperfectly drained

Parent Material: Aeolian (volcanic ash)/Lacustrine/Till

Vegetation: *Carex nigricans* community

Soil Classification:

Remarks: Plot is located in a small enclosed basin, hummocks have a micro-relief of 30 cm. Shape and thickness of the Ah varies greatly from hummock to hummock.



Profile Sketch (1/10 scale)

T-23 (continued)

Horizon	Depth (cm)	
L	2-0	Turfy organic layer.
Ah	0-5	Very dark grayish brown (10YR 3/2 m), dark grayish brown (10YR 4/2 d) silt loam; weak, fine granular; very friable; abundant, fine random roots; clear, irregular boundary; pH 5.1.
Bm1	5-15	Dark reddish brown (5YR 3/4 m), light reddish brown (5YR 6/4 d) silt loam; weak, fine granular; very friable; abundant, fine random roots; clear, broken boundary; pH 5.7.
Ah	15-20	Very dark grayish brown (10YR 3/2 m), dark grayish brown (10YR 4/2 d) silt loam; weak, fine granular; very friable; abundant, fine random roots; clear, broken boundary; pH 5.1.
Bm2	20-25	Strong brown (7.5YR 5/8 m), light yellowish brown (10YR 6/4 d) silt; weak, fine granular; very friable; abundant, fine random roots; clear, broken boundary; pH 6.2.
Ah	25-27	Dark brown (10YR 3/3 m), dark grayish brown (10YR 4/2 d) silt loam; weak, fine granular; very friable; clear, broken boundary.
Bm3	27-34	Yellowish red (5YR 4/8 m), reddish yellow (5YR 6/8 d) silt loam; weak, fine granular; very friable; clear, broken boundary; pH 6.0.
Bm1	34-40	Yellowish red (5YR 4/6 m) silt loam; weak, fine granular; very friable; clear, wavy boundary.
C1	40-47	Strong brown (7.5YR 5/6 m), light yellowish brown (10YR 6/4 d) silt loam; weak, medium platy; friable; few, fine horizontal roots; abrupt, wavy boundary; pH 6.1.
C2	47-65	Yellowish brown (10YR 5/6 m), very pale brown (10YR 7/4 d) silt loam; amorphous to pseudo platy; firm; very few, fine horizontal roots; abrupt, smooth boundary; pH 6.2.
IICg	65-85+	Yellowish brown (10YR 5/4 m), pale brown (10YR 6/3 d) silt loam; amorphous; firm; very few, fine random roots in upper part; 10% coarse fragments (large boulders); pH 5.5.

T-23 CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g H	Na	K	Ca	Mg	SUM	TEC	Avail p ppm	Oxalate Fe %	Oxalate Al %
R70517		Ah	5.1	18	0.6	10.6	16	-	14.6	0.1	0.1	5.5	0.5	20.8	26.5	10	0.41	0.75
518		Bm2	6.2	5	0.3	2.6	10	-	5.6	0.2	tr	0.8	0.3	6.9	15.8	4	0.75	2.46
519		Bm3	6.0	8	0.5	4.8	10	-	10.5	0.1	0.1	0.5	0.3	11.5	27.1	4	0.72	2.94
520		C1	6.1	-	0.3	-	-	-	7.0	0.1	0.1	1.2	0.3	8.7	19.7	4	0.60	2.80
521	(Band)		6.1	-	0.4	-	-	-	7.3	0.1	0.3	0.8	0.1	8.6	26.2	4	0.83	4.05

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm Sand 2-.05	Silt .05-.002	Clay <.002	Moisture Retention % A.D.	1/10 atm	15 atm	Bulk Dens g/cm^3
517	SiL		15	70	15	3.2	130	33	0.5
518	Si		12	84	4	4.2	110	15	-
519	Si-SiL		27	70	3	6.2	84	23	-
520	SiL		23	76	1	3.7	100	17	0.6
521	SiL		29	68	3	5.9	91	26	-

- continued -

T-23 (continued) CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70522		C2	6.2	-	0.1	-	-	-	3.7	0.1	0.1	0.5	0.1	4.5	7.0	4	0.36	1.40
523		IICg	5.5	-	0.1	-	-	-	2.8	tr	0.2	2.5	0.9	6.4	7.6	13	0.35	0.13
524*		Bm1	5.7	13	0.8	7.5	10	-	14.7	0.2	0.4	0.8	0.2	16.3	41.2	4	1.24	4.00

* Bm1 sampled at alternate pit

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
522	SiL		26	71	3	2.5	95	9.6	-
523	SiL		21	60	19	0.7	37	7.7	-
524	SiL		31	63	6	7.8	100	35	0.4

Location: T-24, S. of Sunshine Lodge, 51°04'25, 115°46'50

Elevation: 7500 feet A.M.S.L.

Slope: Depressional basin

Aspect:

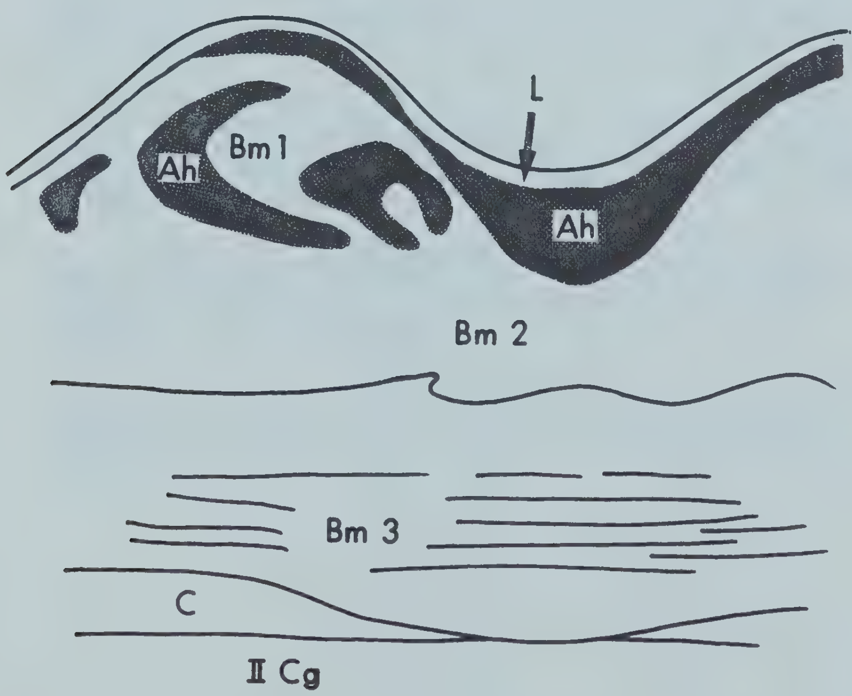
Drainage Class: Imperfectly drained

Parent Material: Aeolian (volcanic ash)/Lacustrine

Vegetation: *Carex nigricans* community

Soil Classification:

Remarks: Plot located in small (75 m by 25 m) depressional basin. Hummocks have a micro-relief of approximately 30 cm.



1/10 scale

T-24 (continued)

Horizon	Depth (cm)	
L	3-0	Fibrous turf; abundant, fine random and abundant, medium horizontal roots; clear, wavy boundary.
Ah	0-9	Black (10YR 2/1 m), dark grayish brown (10YR 4/2 d) silt loam; weak, fine granular; very friable; abundant, fine vertical roots; gradual, irregular boundary; pH 5.3.
Ah+Bm1	1-26 under hummock	Strong brown (7.5YR 5/6 m) silt loam; weak, medium granular; friable; plentiful, fine random roots; clear, broken boundary; pH 5.8.
Bm2	9-19	Yellowish brown (10YR 5/6 m) silt; weak, medium platy; very friable; plentiful, fine vertical roots; gradual, wavy boundary; pH 6.1.
Bm3	19-49	Strong brown (7.5YR 5/6 m) interband and yellowish red (5YR 4/6 m) bands, silt; strong, fine platy; firm; few, fine vertical roots; clear, wavy boundary; pH 6.1.
C	49-53	Light yellowish brown (10YR 6/4 m) silt; amorphous; firm; very few, fine vertical roots; abrupt, smooth boundary; pH 6.5.
IICg1	53-57	Dark grayish brown (2.5Y 4/2 m) silty clay loam; amorphous; firm; very few, fine vertical roots; gradual, smooth boundary.
IICg2	57-77+	Light olive brown (2.5Y 5/4 m) silty clay loam; amorphous; firm; roots to 75 cm; occasional stone; pH 5.9.

T-24 CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70590		Ah	5.3	21	0.9	12.0	13	-	16.1	0.3	0.2	1.0	0.3	17.9	32.2	6	0.68	1.30
591		Bm2	6.1	4	0.2	2.2	9	-	5.4	0.2	tr	0.5	0.2	6.3	11.9	2	0.66	2.50
592		Bm3	6.1	5	0.3	2.8	9	-	6.0	0.1	0.1	0.2	0.2	6.6	19.2	2	0.82	4.26
593		C	6.5	-	0.1	-	-	-	2.4	tr	0.1	2.5	0.3	5.3	6.5	15	0.32	2.05
594		IICg2	6.1	-	0.1	-	-	-	2.1	tr	0.2	3.5	1.6	7.4	8.5	8	0.32	0.18

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
590	SiL		22	73	5	5.2	100	41	0.4
591	Si		14	83	3	3.5	92	14	0.6
592	Si		18	80	2	5.3	86	17	0.6
593	Si		16	81	3	2.4	83	8.1	-
594	SiCL		17	52	31	0.6	36	12	1.4

- continued -

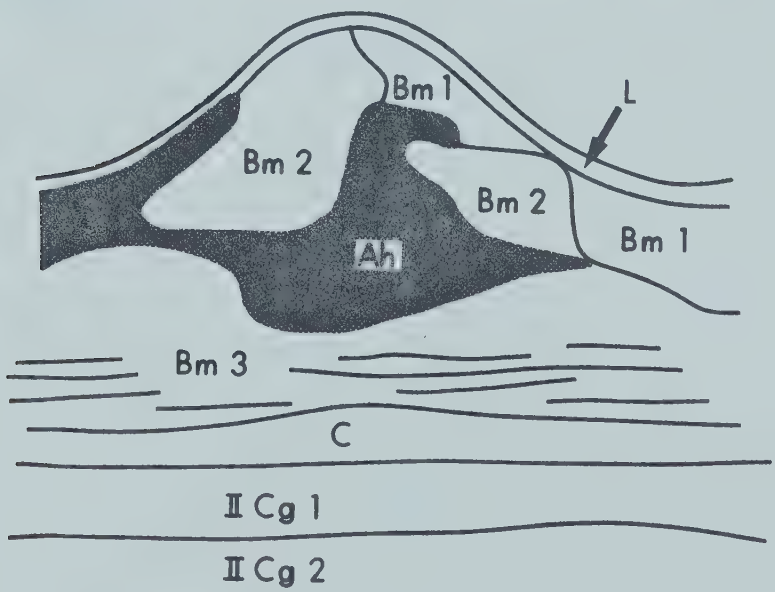
T-24 (continued) CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70595		Ah+Bml	5.9	11	0.5	6.4	13	-	10.6	0.2	tr	0.8	0.1	11.7	24.0	16	0.85	2.44

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
595	SiL		17	78	5	6.2	120	24	0.6

Location:	T-25 , W. of Rock Isle Lake, 51°03'45, 115°46'50
Elevation:	7500 feet A.M.S.L.
Slope:	Depressional basin
Aspect:	
Drainage Class:	Imperfectly drained
Parent Material:	Aeolian (volcanic ash)/Lacustrine
Vegetation:	*Carex nigricans* community
Soil Classification:	
Remarks:	Plot located in small enclosed basin. Surface and profile morphology same as T-24 and T-25.



Profile Sketch (1/10 scale)

T-25 (continued)

Horizon	Depth (cm)	
L	6-0	Turf.
Ah		Dark brown (10YR 3.5/3 m) silt loam; pH 6.2.
Bm1		Reddish brown (5YR 4/4 m) silt loam; pH 6.0.
Bm2		Yellowish brown (10YR 5/6 m) silt loam; pH 6.4.
Bm3		Reddish brown (5YR 5/4 m) interband and strong brown (7.5YR 5/8 m) bands; silt; pH 5.9.
C		Pale brown (10YR 6/3 m).
IICg1		Very dark grayish brown (2.5Y 3/2 m) silt loam.
IICg2		Dark grayish brown (2.5Y 4/2 m) silt loam; pH 6.1.

T-25 CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g H	Na	K	Ca	Mg	SUM	TEC	Avail p ppm	Oxalate Fe %	Oxalate Al %
R70646		Ah	6.2	12	0.4	7.1	16	-	9.3	0.1	0.1	1.2	0.4	11.1	20.1	7	0.48	1.10
647		Bm1	6.0	13	0.8	7.8	9	-	14.6	0.2	0.7	2.0	0.6	18.1	35.2	6	1.53	2.36
648		Bm2	6.4	4	0.2	2.5	11	-	5.7	0.1	tr	1.0	0.4	7.2	12.2	4	0.71	1.95
649a		Bm3	5.9	2	0.3	0.9	3	-	1.6	tr	tr	1.3	0.3	3.2	17.8	6	0.60	2.70
649b		IICg2	6.1	-	-	-	-	-	6.0	0	0.1	1.8	0.9	8.8	6.5	17	0.32	0.11

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm Sand 2-.05	Silt .05-.002	Clay <.002	Moisture Retention % A.D.	1/10 atm	15 atm	Bulk Dens g/cm^3
646	SiL		16	79	5	4.0	110	28	-
647	SiL		17	82	1	7.7	86	30	-
648	SiL		26	70	4	3.6	86	14	-
649a	Si		19	80	1	5.2	76	19	-
649b	SiL		20	63	17	0.6	34	7.4	-

Location:	T-26, N. of Twin Cairn Mtn., $51^{\circ}04'40$, $115^{\circ}48'10$
Elevation:	7500 feet A.M.S.L.
Slope:	0 to 1%
Aspect:	
Drainage Class:	Poorly drained
Parent Material:	Alluvium
Vegetation:	*Eriophorum scheuchzeri* community
Soil Classification:	Orthic Humic Gleysol
Remarks:	Meltwater ponds in this area in late summer. Considerable hummocky micro-relief. Gravelly wash on surface of bare patches.

Horizon	Depth (cm)	
Ahg	0-12	Dark gray (5Y 4/1 m), light yellowish brown (2.5Y 6/4 d) loam; weak, medium subangular blocky; sticky; abundant, fine vertical roots; gradual, smooth boundary; 10 to 15 cm thick; pH 5.6.
Bg	12-20	Olive brown (2.5Y 4/4 m), light yellowish brown (2.5Y 6/4 d) loam; many, coarse, prominent (10YR 5/6 m) mottles; amorphous; firm; very few, fine vertical roots; 5% coarse fragments; diffuse, wavy boundary; 5 to 10 cm thick; pH 7.3.
Cg	20-50	Gray (5Y 5/1 m), light yellowish brown (2.5Y 6/4 d) silt loam; many, coarse, prominent (10YR 5/6 m) mottles; amorphous; slightly sticky; 20% coarse fragments; pH 6.9.
R	50+	Bedrock.

T-26 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70500	0-12	Ahg	5.6	2	0.1	1.0	7	-	2.5	0.1	0.2	8.0	3.4	14.2	6.4			
501	12-20	Bg	7.3	0.1	tr	0.1	2	0.8	-	tr	0.1	16.5	4.5	21.1	5.0			
502	20-50	Cg	6.9	-	-	-	-	-	0.8	tr	0.1	4.5	2.2	7.6	5.2	2		

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
500	L	-	43	42	15	8.8	39	9.6	
501	L	5	42	38	20	0.7	28	10	
502	SiL	20	28	57	15	0.8	31	9.0	

Location:	T-27, E. of Wa-Wa Ridge, 51°05'01, 115°47'40
Elevation:	7700 feet A.M.S.L.
Slope:	Depressional area
Aspect:	
Drainage Class:	Very poorly drained
Parent Material:	Water-sorted colluvium
Vegetation:	*Eriophorum angustifolium* community
Soil Classification:	Rego Humic Gleysol
Remarks:	This is a groundwater discharge area with considerable seepage at the surface. There are large colluvial boulders scattered throughout the basin. Mottles occur in positions of greatest seepage volume. There is no micro-relief present, surface is very flat. Soil temperatures (August) 13°C at 20 cm, 11°C at 50 cm.

Horizon	Depth (cm)	
Ahg	0-10	Very dark gray (5Y 3/1 m), light olive brown (2.5Y 5/4 d) gravelly sandy loam; weak, medium granular; slightly sticky; plentiful, fine random roots; 15% coarse fragments; abrupt, wavy boundary; 8 to 12 cm thick; pH 6.3.
Cg1	10-35	Gray (N5/ m)light gray (5Y 6/1 d) silt loam; common, fine distinct olive (5Y 4/4 m) mottles; amorphous; firm; very few, fine random roots; diffuse, smooth boundary; pH 5.8.
Cg2	35-55	Gray (N5/ m), olive (5Y 5/3 d) silt loam; many, coarse, prominent brown (10YR 4/3 m) mottles; amorphous; firm; 5% coarse fragments; diffuse, smooth boundary; pH 6.9.
Cg3	55+	Gray (N5/ m) silt loam; amorphous; firm.

T-27 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70540	0-10	Ahg	6.3	8	0.4	4.5	10	-	5.0	0.1	0.1	6.8	1.5	13.5	17.9	4	-	-
541	10-35	Cg1	5.8	-	-	-	-	-	1.4	tr	0.1	4.0	2.0	7.5	3.9	2	-	-
542	35-55	Cg2	6.9	-	-	-	-	-	0.3	tr	0.1	4.9	2.0	7.3	6.0	0	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
540	L	15	45	42	13	3.4	72	14	-
541	SiL	-	33	62	5	1.1	32	8.1	-
542	SiL	5	28	51	21	0.4	34	12	-

Location:	T-28, N. of Quartz Hill, 51°02'45, 115°46'28
Elevation:	7950 feet A.M.S.L.
Slope:	15%
Aspect:	West
Drainage Class:	Rapidly drained
Parent Material:	Colluvium/Glacial till
Vegetation:	*Dryas* community
Soil Classification:	Alpine Eutric Brunisol
Remarks:	Slope instability is expressed by buried Ah lens on one side of pit. The IICk is cemented with carbonates. Bedrock is quite shallow, perhaps 60-80 cm.

Horizon	Depth (cm)	
L	4-0	Fibrous turf; abundant, fine random and abundant, medium horizontal roots; clear, wavy boundary; 1 to 5 cm thick.
Ah	0-5	Black (10YR 2/1 m), very dark gray (10YR 3/1 d) silt loam; moderate, fine granular; very friable; plentiful, fine random roots 1 to 12 cm thick; 20% coarse fragments; pH 7.3.
Bmk	5-12	Dark brown (7.5YR 4/4 m, 10YR 4/3 d) silt loam; weak, fine granular; very friable; few, fine vertical roots; very weakly effervescent; less than 5% coarse fragments; clear, wavy boundary; 3 to 10 cm thick; pH 7.7.
IICk	12+	Brown (10YR 5/3 m), light gray (10YR 6.5/1 d) very gravelly loam; amorphous; very firm; strongly effervescent; 80% coarse fragments; pH 7.9.

T-28 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70627	0-5	Ah	7.3	25	1.2	14.5	12	0.6	-	0.1	0.3	66.2	7.3	73.9	75.1	4	0.63	0.99
628	5-12	Bmk	7.7	7	0.4	4.1	11	3.0	-	-	-	-	-	-	29.8	0	1.29	1.02
629	12-20	IICk	7.9	-	-	-	-	30.9	-	-	-	-	-	-	4.9	5	0.14	0.05

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
627	SiL	10	23	74	3	6.9	130	63	-
628	SiL	5	17	71	12	4.1	73	19	-
629	L	80	39	37	24	0.4	23	6.9	-

Location:	T-29, S. of Rock Isle Lake, 51°03'30, 115°46'30
Elevation:	7600 feet A.M.S.L.
Slope:	40-60%
Aspect:	
Drainage Class:	Rapidly drained
Parent Material:	Colluvium
Vegetation:	*Anemone occidentalis* community
Soil Classification:	Cumulic Regosol (II)
Remarks:	The turfy L horizon is very compact and root bound. The profile is cumulic; due to very active soil creep the A and C horizons are mixed together and move downslope. There is slow groundwater seepage below 25 cm.

Horizon	Depth (cm)	
L	5-0	Dark yellowish brown (10YR 4/4 m, 4/4 d) fibrous turf; abundant, fine random roots; gradual, wavy boundary; 3 to 6 cm thick; pH 5.5.
Ah1	0-15	Dark brown (10YR 3/3 m), dark grayish brown (10YR 4/2 d) loam; weak, fine granular; friable; plentiful, fine vertical roots; 10% coarse fragments; diffuse, wavy boundary; pH 6.2.
Ah2	15-35	Very dark grayish brown (10YR 3/2 m), dark grayish brown (10YR 4/2 d) silt loam; weak, fine granular; friable; plentiful, fine vertical roots; 20% coarse fragments; diffuse, wavy boundary; pH 6.6.
AC	35-80+	Dark brown (10YR 3/3 m), brown (10YR 4.5/3 d) silt loam; moderate, medium subangular blocky; friable; few, fine vertical roots to 80 cm; weakly effervescent; 10% coarse fragments; pH 6.7.

T-29 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70632	5-0	L	5.5	11	0.6	6.6	10	-	12.2	tr	1.1	3.7	1.5	18.5	27.5	20	-	-
633	0-15	Ah1	6.2	9	0.5	5.2	10	-	8.6	tr	0.1	6.3	1.1	16.0	24.8	19	-	-
634	15-35	Ah2	6.6	7	0.4	4.3	10	-	6.0	tr	0.1	9.2	1.5	16.8	21.2	13	-	-
635	35-60	AC	6.7	4	0.2	2.5	11	-	3.8	tr	0.1	7.2	1.7	12.8	13.1	7	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
632	SiL	-	35	57	8	4.3	57	28	-
633	SiL	10	31	64	5	4.1	57	21	-
634	SiL	20	28	60	12	3.1	56	19	-
635	SiL	10	22	63	15	2.6	44	13	-

Location:	T-30, Lookout Mtn., 51°04'20, 115°46'10
Elevation:	7730 feet A.M.S.L.
Slope:	35-40%
Aspect:	West
Drainage Class:	Rapidly drained
Parent Material:	Colluvium (plus aeolian at surface)
Vegetation:	*Phyllodoce glanduliflora* community
Soil Classification:	Alpine Dystric Brunisol
Remarks:	Truncation of profile and buried surface horizons show significance of downslope soil creep. Turf and Ah are sliding over the turf layers downslope.

Horizon	Depth (cm)	
L	2-0	Fibrous turf; plentiful, fine vertical and abundant, medium horizontal roots; clear, wavy boundary; 1 to 4 cm thick.
Ah	0-5	Very dark grayish brown (10YR 3/2 m), dark grayish brown (10YR 4/2 d) silt loam; moderate, fine granular; friable; plentiful, fine and medium random roots; 10% coarse fragments; clear, wavy boundary; 2 to 6 cm thick; pH 5.1.
Lb	5-7	Buried fibrous turf; plentiful, fine vertical and plentiful, medium horizontal roots; clear, wavy boundary; 1 to 4 cm thick.
Bm	7-17	Dark brown (7.5YR 4/4 m, 10YR 4/3 d) silt loam; moderate, fine granular; friable, few, fine random roots; 15% coarse fragments; clear, wavy boundary; 8 to 15 cm thick; pH 5.8.
BC	17-30	Very dark grayish brown (10YR 3/2 m), dark grayish brown (10YR 4/2 d) gravelly sandy loam; moderate, fine granular, friable; plentiful, fine vertical roots; weakly effervescent; 50% coarse fragments; gradual, wavy boundary; 5 to 15 cm thick; pH 7.0.
Ck	30+	Grayish brown (2.5Y 5/2 m), light brownish gray (10YR 6/2 d) very gravelly sandy loam; weak, fine granular; loose; few, fine vertical roots to 50 cm; moderately effervescent; 60% coarse fragments; pH 7.8.

T-30 CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70581	0-5	Ah	5.1	17	0.6	10.0	16	-	15.8	0.1	0.4	3.5	1.6	21.4	28.8	4	0.85	0.26
582	7-17	Bm	5.8	5	0.3	3.2	12	-	7.3	tr	0.1	2.5	0.8	10.7	18.2	0	0.77	0.77
583	17-30	BC	7.0	3	0.2	1.6	9	9.1	-	tr	0.1	8.0	3.5	11.6	10.0	2	0.50	0.39
584	30-40	Ck	7.9	-	-	-	-	80.6	-	-	-	-	-	-	1.1	1	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
581	SiL	10	38	54	8	2.8	64	29	-
582	SiL	15	37	53	10	2.6	48	34	-
583	SL	50	49	42	9	1.0	43	16	-
584	SL	60	55	40	5	0.1	21	11	-

Location:	T-31, SW of Lookout Mtn., 51°04'01, 115°45'55
Elevation:	7740 feet A.M.S.L.
Slope:	10%
Aspect:	Southwest
Drainage Class:	Surface - well drained, some seepage at 20 cm +.
Parent Material:	Alluvium
Vegetation:	*Salix arctica* community
Soil Classification:	Cumulic Regosol (calcareous) (I)
Remarks:	The plot is located in a drainage channel, subject to annual flooding and deposition of fresh parent material. There is a thin layer of ash at 40 cm depth.

Horizon	Depth (cm)	
L	3-0	Fibrous turf; plentiful, fine random and abundant, medium horizontal roots; 2 to 4 cm thick.
Ck1	0-20	Brown (10YR 4/3 m), light brownish gray (10YR 6/3 d) sandy loam; amorphous; friable; few, fine vertical roots; weakly effervescent; less than 5% coarse fragments; diffuse, smooth boundary; pH 7.9.
Ck2	20-55	Dark brown (10YR 3/3 m), grayish brown (10YR 5/2 d) silt loam; amorphous; friable; very few, fine vertical roots; weakly effervescent; abrupt, smooth boundary; pH 8.0.
Ck3	55-85	Dark brown (10YR 4/3 m) gravel; single grained; loose; few, fine vertical roots to 60 cm; abrupt, smooth boundary; pH 8.0.
Ck4	55-105	Dark brown (10YR 3/3 m) very fine sandy loam; amorphous; friable; weakly effervescent; less than 5% coarse fragments; abrupt, smooth boundary; pH 8.0.
Ck5	105+	Dark brown (10YR 3/3 m) very cobbly sandy loam; amorphous; friable; weakly effervescent.

T-31 CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70588	0-20	Ck1	7.9	-	0.1	-	-	74.7	-	-	-	-	-	-	8.0	2	-	-
589	20-55	Ck2	8.0	-	0.2	-	-	42.8	-	-	-	-	-	-	14.1	10	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
588	SL	5	60	36	4	0.6	46	8.3	-
589	SiL	-	55	42	3	1.5	65	12	-

Location:	T-32, NE of Rock Isle Lake, 51°03'40, 115°46'50
Elevation:	7600 feet A.M.S.L.
Slope:	20%
Aspect:	South
Drainage Class:	Rapidly drained
Parent Material:	Glacial till/Bedrock
Vegetation:	*Kobresia myosuroides* community
Soil Classification:	Lithic Alpine Eutric Brunisol
Remarks:	Kobresia turf is very firm and compact. Bedrock is close to surface. The upper 20 cm of the till appears to have been moved by frost or colluvial action (or by ground squirrel activity).

Horizon	Depth (cm)	
Ah	0-6	Very dark brown (10YR 2/2 m), very dark grayish brown (10YR 3/2 d) silt loam; compactly rooted, turfy; abundant, fine random roots; 10% coarse fragments; clear, wavy boundary; 4 to 10 cm thick; pH 6.0.
Bmk	6-16	Dark yellowish brown (10YR 3/4 m), dark brown (10YR 4/3 d) silt loam; weak, fine granular; very friable; abundant, fine vertical roots (upper Bm is turfy); lower Bm is moderately effervescent; 15% coarse fragments; gradual, wavy boundary; 5 to 15 cm thick; pH 7.0.
BC	16-21	Dark brown (10YR 4/3 m) gravelly sandy loam; moderate, medium granular; friable; plentiful, fine vertical roots; strongly effervescent; 50% coarse fragments; gradual, broken boundary; 0 to 10 cm thick; pH 7.5.
Ck	21-40	Brown (10YR 5/3 m), light brownish gray (10YR 6/2 d) very gravelly sandy loam; amorphous; moist-friable; dry-hard; few, fine vertical roots to 40 cm; strongly effervescent; 75% coarse fragments (to cobble size); abrupt, irregular boundary; pH 7.7.
R	40+	Shattered limestone bedrock.

T-32 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70615	0-6	Ah	6.0	18	0.9	10.3	12	-	8.0	0.1	0.9	15.8	5.3	30.1	42.2	2	0.61	0.38
616	6-16	Bmk	7.0	8	0.4	4.7	11	5.9	-	0.1	0.3	20.0	7.7	28.1	28.7	2	0.66	0.57
617	21-40	Ck	7.7	-	-	-	-	72.4	-	-	-	-	-	-	2.4	5	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
615	SiL	10	34	57	9	4.8	76	36	-
616	SiL	15	30	57	13	2.1	61	20	-
617	SL	50	62	30	8	0.2	22	3.0	-

Location: T-33, Base of Quartz Hill, 51°02'15, 115°45'35

Elevation: 7850 feet A.M.S.L.

Slope: 60%

Aspect: East

Drainage Class: Rapidly drained

Parent Material: Colluvium

Vegetation: *Saxifraga lyallii* community

Soil Classification: Orthic Regosol

Remarks: This plot is located on a steep, active talus slope. Mass wasting is very active as reflected by the lack of pedogenic development.

Horizon	Depth (cm)	
L	4-0	Black (5YR 2/1 m), very dark grayish brown (10YR 3/2 d) fibrous turf; abundant, fine random roots; pH 6.8.
C1	0-20	Dark grayish brown (10YR 3.5/2 m), grayish brown (10YR 4.5/2 d) gravelly silt loam; weak, fine granular; very friable; abundant, fine vertical roots; 30% coarse fragments; 15 to 25 cm thick; pH 7.6.
C2 (1)	20-45	Very dark grayish brown (10YR 3/2 m), brown (10YR 4/3 d) bouldery silt loam; weak, fine granular and weak, coarse subangular blocky; very friable; plentiful, fine vertical roots; 30% coarse fragments (boulder size); pH 7.6.
C2 (2)	45-80+	Very dark grayish brown (10YR 3/2 m), brown (10YR 5/3 d) bouldery silt loam; fragmental; friable; very few, fine vertical roots; 30% coarse fragments (boulder size); pH 7.7.

T-33 CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g H	Na	K	Ca	Mg	SUM	TEC	Avail p ppm	Oxalate Fe %	Oxalate Al %
R70480	4-0	L	6.8	31	1.4	17.8	12	-	7.4	0.1	2.2	50.8	16.5	77.0	76.0	48	-	-
481	0-20	C1	7.6	3	0.2	1.8	9	3.1	-	-	-	-	-	-	-	4	-	-
482	20-45	C2(1)	7.6	2	0.2	1.2	7	2.3	-	-	-	-	-	-	-	1	-	-
483	45-80	C2(2)	7.7	-	0.1	-	-	1.6	-	-	-	-	-	-	-	6	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm Sand 2-.05	Silt .05-.002	Clay <.002	Moisture Retention % A.D.	1/10 atm	15 atm	Bulk Dens g/cm^3
480	-	-	-	-	-	7.8	120	80	-
481	SiL	30	27	50	23	1.7	44	13	-
482	L	30	39	46	15	1.6	39	9.1	-
483	L	30	44	43	13	1.4	32	7.3	-

Location:		T-34, E. of Quartz Ridge, 51°02'22, 115°45'20
Elevation:		7340 feet A.M.S.L.
Slope:		2%
Aspect:		
Drainage Class:		Poorly drained
Parent Material:		Alluvium
Vegetation:		*Salix barrattiana* community
Soil Classification:		Cumulic Regosol (I)
Remarks:		Plot is located in a snow-melt drain. There is limited groundwater seepage. Material is very heterogeneous, varying from sandstone-derived to siltstone-and shale-derived alluvium material.
Horizon	Depth (cm)	
F	3-0	Black (10YR 3/1 m, 2/1 d) slightly decomposed organic matter; plentiful, fine and medium random roots; 0 to 5 cm thick; abrupt, smooth boundary; pH 6.4.
Ah1	0-4	Black (10YR 2/1 m), black (10YR 2/1 d) loam; moderate, fine granular; slightly hard; few, medium horizontal and plentiful, fine random roots; abrupt, smooth boundary; pH 6.1.
C	4-5	Very dark gray (10YR 3/1 m), dark gray (10YR 4/1 d) alluvial deposit.
Ah2	5-15	Very dark brown (10YR 2/2 m), very dark gray (10YR 3/1 d) loam; weak, fine granular to weak, medium blocky; slightly hard; plentiful, fine random and few, medium random roots; abrupt, smooth boundary; pH 6.7.
Bm	15-20	Brown (7.5YR 4/4 m, 10YR 4/3 d) loam; weak, coarse subangular blocky; very friable; few, fine random roots; less than 5% coarse fragments; 1 to 8 cm thick; gradual, irregular boundary; pH 7.0.
Ah3	20-23	Black (10YR 2/1 m) gravelly loam; amorphous; loose; 50% coarse fragments; clear, smooth boundary; pH 6.9.

- continued -

T-34 (continued)

Horizon	Depth (cm)	
IIC	23-53	Brown (10YR 5/3 m, 5/3 d) gravel; amorphous; loose; few to very few, fine vertical roots; 90% coarse fragments; clear, smooth boundary; pH 6.9.
IIIC	53+	Dark grayish brown (2.5Y 4/2 m), light brownish gray (10YR 6/2 d) gravelly silt loam; amorphous; friable; 25% coarse fragments; pH 7.1.

T-34 CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70474	3-0	F	6.4	49	2.3	28.5	12	-	15.1	0.2	1.8	65.0	13.9	96.0	106.8	33	-	-
475	0-4	Ah1	6.1	39	1.9	22.4	12	-	14.0	0.1	0.9	57.1	16.3	88.4	95.4	22	-	-
476	5-15	Ah2	6.7	21	1.3	12.0	9	-	8.0	0.1	0.1	35.5	9.4	53.1	61.8	3	0.86	2.26
477	15-20	Bm	7.0	13	0.9	7.5	9	-	4.8	0.1	0.1	22.5	6.2	33.7	52.5	2	1.06	4.00
478	25-53	IIC	6.9	0.8	0.1	0.5	5	-	1.0	tr	tr	3.6	1.6	6.2	6.4	4	0.24	0.12
479	53-70	IIC	7.1	-	-	-	-	0.7	-	tr	tr	3.0	1.1	4.1	5.6	2	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
474		-	-	-	-	12	160	130	0.5
475		-	-	-	-	12	140	100	0.6
476	SiL	-	18	68	14	10	100	60	-
477	SiL	5	15	76	9	10	100	47	-
478	L	90	42	47	11	0.8	21	6.7	-
479	L	25	45	41	14	0.6	25	6.1	-

Location:	T-35, W. of Windy Point, $51^{o}02'23$, $115^{o}45'45$
Elevation:	7430 feet A.M.S.L.
Slope:	0 to 1%
Aspect:	
Drainage Class:	Poorly drained
Parent Material:	Alluvium
Vegetation:	*Salix barrattiana*
Soil Classification:	Cumulic Regosol (I)
Remarks:	This plot is located in a drainage channel where runoff water likely ponds for some time. The profile indicates periodic alluvial deposition. Soil is hard and amorphous when dry.

Horizon	Depth (cm)	
L	2-0	Undecomposed moss litter.
Ah1	0-5	Dark brown (10YR 3/3 m), grayish brown (10YR 5/2 d) silt loam; weak, medium subangular blocky; friable; diffuse, wavy boundary; 0 to 8 cm thick.
Ah2	5-10	Black (10YR 2/1 m), dark grayish brown (10YR 4/2 d) silt loam; weak, medium subangular blocky; firm; plentiful, fine random roots; diffuse, wavy boundary; 3 to 15 cm thick.
Ah3	10-18	Dark brown (10YR 3/3 m), grayish brown (10YR 4/2 d) silt loam; weak, medium subangular blocky; firm; gradual, smooth boundary; 5 to 10 cm thick; pH 6.5.
IIC	18-33	Light yellowish brown (10YR 6/4 m), very pale brown (10YR 7/3 d) silt loam; amorphous; hard; very few, fine vertical roots; very weakly effervescent; clear, smooth boundary; 12 to 20 cm thick; pH 7.1.
IIICk	33-90+	Olive brown (2.5Y 4/4 m), light brownish gray (10YR 6/2 d) loam; amorphous; hard; very few, fine random roots; strongly effervescent; pH 7.7.

T-35 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g H	Na	K	Ca	Mg	SUM	TEC	Avail P ppm	Oxalate Fe %	Oxalate Al %
R70503	10-18	Ah3	6.5	10	0.6	5.9	9	-	5.4	0.1	0.1	17.5	4.9	28.0	25.1	1	-	-
504	18-33	IIC	7.1	-	-	-	-	0.5	-	0.1	0.2	5.0	0.9	6.2	5.0	5	-	-
505	33-90	IIICk	7.7	-	-	-	-	32.4	-	-	-	-	-	-	3.4	0	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm Sand 2-.05	Silt .05-.002	Clay <.002	Moisture Retention % A.D.	1/10 atm	15 atm	Bulk Dens g/cm^3
503	SiL	-	20	79	1	4.2	110	33	-
504	SiL	-	17	79	4	1.0	75	8.6	-
505	L	-	39	51	10	0.2	28	5.3	-

Location:	T-36, S. of Sunshine Village, 51°02'46, 115°45'55
Elevation:	7580 feet A.M.S.L.
Slope:	2%
Aspect:	
Drainage Class:	Imperfectly drained
Parent Material:	Aeolian/Glacial till
Vegetation:	*Salix arctica*
Soil Classification:	Alpine Dystric Brunisol
Remarks:	The surface 10-15 cm of aeolian (ash) is variable to 0 cm where boulders protrude. Buried Ah seems to have developed in surface of the till and later covered with ash.

Horizon	Depth (cm)	
L	2-0	Fibrous turf
Ah	0-5	Very dark grayish brown (10YR 3/2 m), brown (10YR 5/3 d) silt loam; weak, fine granular; friable; plentiful, fine random roots; abrupt, smooth boundary; 2 to 15 cm thick; pH 6.2.
Bm	5-13	Strong brown (7.5YR 5/8 m), brownish yellow (10YR 6/6 d) silt loam; weak, coarse subangular blocky; friable; plentiful, fine random roots; clear, smooth boundary; 3 to 12 cm thick; pH 6.5.
Ahb	13-18	Dark brown (10YR 3/3 m) gravelly loam; weak, fine granular; friable; plentiful, fine random roots; 40% coarse fragments; clear, irregular boundary; 0 to 8 cm thick.
C	18-80+	Yellowish brown (10YR 5/4 m), brown (10YR 5/3 d) loam; fragmental; friable; few, fine vertical roots; 20% coarse fragments; pH 6.2.

T-36 CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70514	0-5	Ah	6.2	16	1.0	9.2	9	-	9.7	0.1	0.3	9.8	4.5	24.4	38.2	13	1.03	2.20
515	5-13	Bm	6.5	7	0.5	4.1	9	-	5.4	0.1	0.1	5.4	1.6	12.6	30.2	6	1.02	2.68
516	13-80	C	6.2	-	-	-	-	-	1.3	tr	0.1	2.4	1.3	5.1	5.2	12	0.31	0.10

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
514	SiL	-	21	76	3	7.1	105	40	
515	SiL	-	14	78	8	7.8	89	24	
516	SiL-L	20	30	51	19	0.3	29	7.1	

Location:	T-37, S. of Sunshine Village, 51°02'45, 115°45'55
Elevation:	7550 feet A.M.S.L.
Slope:	Level
Aspect:	
Drainage Class:	Imperfectly drained
Parent Material:	Aeolian/Glacial till
Vegetation:	*Salix arctica* community
Soil Classification:	Alpine Eutric Brunisol
Remarks:	The Ah seems to be developed in an aeolian overlay. Drainage is better than T-38 due to location on slightly raised area.

Horizon	Depth (cm)	
Ah	0-12	Very dark grayish brown (10YR 3/2 m), dark grayish brown (10YR 4/2 d) silt loam; weak, fine granular; very friable; plentiful, fine random roots (upper 2 cm turfy); 5% coarse fragments; clear, wavy boundary; 6 to 12 cm thick; pH 6.7.
IIBmk	12-27	Dark brown (10YR 3/3 m), grayish brown (10YR 5/2 d) silt loam to loam; moderate, fine granular; friable; few, fine vertical roots; weakly effervescent; 20% coarse fragments; gradual, smooth boundary; pH 7.3.
IICk	27+	Dark grayish brown (2.5Y 4/2 m), grayish brown (10YR 5.5/2 d) gravelly loam; no roots; weakly effervescent; 30% gravel; pH 7.9.

T-37 CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70511	0-12	Ah	6.7	8	0.6	4.7	.8	-	3.8	0.1	0.2	16.8	5.3	26.2	27.7	5	0.79	1.20
512	12-27	IIBmk	7.3	1	0.1	0.8	7	0.6	-	tr	0.1	8.8	4.2	13.1	10.4	1	0.39	0.14
513	27-40	IICk	7.9	-	-	-	-	51.4	-	-	-	-	-	-	3.3	2	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
511	SiL	5	29	58	13	3.0	105	29	-
512	SiL-L	20	26	49	25	1.1	32	9.6	-
513	L-SL	30	48	41	11	0.1	22	2.1	-

Location:	T-38, W. of Windy Point, 51°02'44, 115°45'54
Elevation:	7550 feet A.M.S.L.
Slope:	1%
Aspect:	
Drainage Class:	Poorly drained
Parent Material:	Glacial till
Vegetation:	*Carex saxitilis* L. var. *major* Olney
Soil Classification:	Rego Humic Gleysol
Remarks:	There is no mottling or prominent gleying but the colors are dull and structure is massive; therefore soil put into the Gleysolic Order. The Ah tends to be thicker under the small (2-6") micro-relief clumps. Parent material appears to be glacial till that has been somewhat sorted by water.

Horizon	Depth (cm)	
Ahgj	0-9	Dark brown (10YR 3/3 m), dark brownish gray (10YR 4/2 d) silt loam; weak, fine granular; very friable; plentiful, fine vertical roots (upper 2 cm turfy); 10% coarse fragments; clear, wavy boundary; 5 to 10 cm thick; pH 6.1.
Cg1	9-29	Yellowish brown (10YR 4.5/4 m), grayish brown (10YR 5/2 d) silt loam; very coarse platy and weak, fine subangular blocky; friable; few, fine vertical roots; 20% coarse fragments; diffuse, smooth boundary; pH 6.3.
Cg2	29-60	Dark grayish brown (2.5Y 4/2 m), brown (10YR 5/3 d) gravelly loam; amorphous; friable; very weakly effervescent; 30% coarse fragments; pH 7.5.
Cg3	60+	Very stoney loam; no roots.

T-38 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70508	0-9	Ahgj	6.1	14	0.8	7.9	10	-	7.4	tr	0.1	13.0	4.1	24.6	28.5	15	-	-
509	9-29	Cg1	6.3	-	-	-	-	-	1.9	tr	0.1	15.0	2.2	19.2	6.7	4	-	-
510	29-60	Cg2	7.5	-	-	-	-	9.0	-	-	-	-	-	-	4.7	9	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
508	SiL	10	20	76	4	5.4	76	29	0.5
509	SiL-L	20	33	51	16	0.7	30	7.0	1.3
510	L	30	40	47	13	0.5	27	6.1	-

Location:	T-39, SE of Ski Patrol Hut, 51°04'44, 115°46'45
Elevation:	7140 feet A.M.S.L.
Slope:	50%
Aspect:	North
Drainage Class:	Rapidly drained at surface, some seepage
Parent Material:	Colluvium
Vegetation:	*Anemone occidentalis* community
Soil Classification:	Cumulic Regosol (II)
Remarks:	Unstable colluvial slope, with groundwater seepage. The AC seems to be a cumulative horizon with inclusions of Ah and volcanic ash. AC is well rooted (from *Carex* spp). C is a seepage plane - seems to be contact between upper (active) and lower colluvium.

Horizon	Depth (cm)	
Ah	0-5	Very dark grayish brown (10YR 3/2 m), grayish brown (10YR 5/2 d) loam; abundant, fine random roots; gradual, smooth boundary; pH 5.1.
AC	5-35	Yellowish brown (10YR 5/6 m) and dark yellowish brown (10YR 4/4 m), pale brown (10YR 5.5/3 d) silt loam; moderate, fine granular; friable; plentiful, fine vertical roots; 10% coarse fragments; pockets of ash; gradual, smooth boundary; pH 6.0.
C	35-36	Dark brown (10YR 3/3 m) silt loam; charcoal fragments present; abrupt, broken boundary; 0 to 1 cm thick.
IICk	36+	Grayish brown (10YR 5/2 m), light brownish gray (10YR 6/2 d) gravelly sandy loam; fragmental; friable; few, fine vertical roots to 50 cm; 40% coarse fragments; pH 7.5.

T-39 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70653	0-5	Ah	5.1	9	0.5	5.3	11	-	8.7	tr	1.2	2.7	1.3	13.9	21.1	17	0.82	0.29
654	5-35	AC	6.0	4	0.2	2.0	9	-	4.8	tr	0.1	3.0	0.7	8.6	13.4	8	0.82	0.48
655	36-50	IICk	7.5	-	-	-	-	84.3	-	-	-	-	-	-	0.5	1	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
653	L	-	27	48	25	25	55	25	-
654	SiL	10	32	50	18	2.2	40	14	-
655	SL	40	68	26	6	0.1	16	1.6	-

Location:	T-40, E. of Ski Patrol Hut, 51°04'44, 115°46'44
Elevation:	7200 feet A.M.S.L.
Slope:	55-60%
Aspect:	North
Drainage Class:	Rapidly drained
Parent Material:	Colluvium
Vegetation:	*Saxifraga lyallii* community
Soil Classification:	Alpine Eutric Brunisol (calcareous)
Remarks:	Late snowbed accumulation area. This is a fairly active colluvial slope with thin buried Ah horizons. *S. lyallii* does not form a compact turf, roots are all vertical and do not bind very effectively. Clumps of Saxifraga form micro-terraces.

Horizon	Depth (cm)	
L	1-0	Fibrous turf; clear, wavy boundary; 1 to 3 cm thick.
Ahk	0-3	Dark grayish brown (10YR 4/2 m), grayish brown (10YR 5/1 d) loam; weak, fine granular; friable; few, fine vertical roots; 20% cobble-sized fragments; gradual, broken boundary; 0 to 6 cm thick; pH 7.7.
Bmk	3-9	Dark yellowish brown (10YR 4/4 m), grayish brown (10YR 4/2 d) silt loam; weak; fine granular; friable; few, fine vertical roots; 20% cobble-sized fragments; clear, broken boundary; 0 to 10 cm thick; pH 7.9.
IICk	9-80+	Grayish brown (10YR 5/2 m), light gray (10YR 6/1 d) very gravelly sandy loam; single grain; friable; very few, fine vertical roots to 40 cm; weakly effervescent; pH 7.9.

T-40 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70650	0-3	Ahk	7.7	3	0.2	1.7	9	20.6	-	-	-	-	-	-	12.0	15	0.62	0.42
651	3-9	Bmk	7.9	3	0.2	1.8	9	8.9	-	-	-	-	-	-	14.2	18	0.82	0.62
652	9-80	IICk	7.9	-	-	-	-	82.4	-	-	-	-	-	-	0.4	2	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
650	L	20	38	47	15	1.7	39	11	-
651	SiL	20	30	52	18	2.2	41	14	-
652	SL	-	55	39	6	0.1	18	1.4	-

Location:	T-41, S.E. of Wa-Wa Ridge, 51°04'50, 115°47'50
Elevation:	7580 feet A.M.S.L.
Slope:	15%
Aspect:	East
Drainage Class:	Moderately well drained
Parent Material:	Alluvium and colluvium/shale bedrock
Vegetation:	*Carex nigricans* community
Soil Classification:	Cumulic Regosol (I)
Remarks:	The plot is located in a meltwater drainage area and possibly receives some groundwater seepage. The Ah seems to be cumulic, possibly due to alluvial deposition or churning by mass wasting. The Bm is an area of water movement, as water is perched on top of the shales.

Horizon	Depth (cm)	
L	4-0	Dark grayish brown (10YR 4/2 d) fibrous turf; abundant, fine and medium random roots; clear, smooth boundary; 2 to 5 cm thick; pH 6.0.
Ah1	0-8	Dark brown (10YR 3/3 m), grayish brown (10YR 5/2 d) silt loam; weak, fine granular; very friable; abundant, fine random roots; diffuse, wavy boundary; 5 to 10 cm thick; pH 5.8.
Ah2	8-25	Dark brown (10YR 3.5/3 m), grayish brown (10YR 5/2 d) loam; weak, fine granular; very friable; plentiful, fine vertical roots; clear, wavy boundary; 15 to 20 cm thick; pH 5.8.
C	25-45	Dark grayish brown (10YR 4/2 m), pale brown (10YR 6/2.5 d) gravelly sandy loam; moderate, medium subangular blocky; friable; few, fine vertical roots; clear, wavy boundary; pH 5.8.
Bm	45-65	Dark brown (7.5YR 4/4 m), strong brown (7.5YR 5/6 d) silt loam; weak, fine granular; friable; few, fine vertical roots; gradual, broken boundary; 2 to 25 cm thick; pH 6.5.
IIC	66+	Shaley silt loam (weathered shales).

T-41 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70543	4-0	L	6.0	17	0.8	9.8	12	-	13.8	0.1	1.4	3.8	2.5	21.6	30.3	20	-	-
544	0-8	Ahl	5.8	7	0.4	4.0	10	-	7.6	tr	tr	1.6	0.4	9.6	17.9	10	-	-
545	25-45	C	5.8	-	0.1	-	-	-	2.2	tr	tr	3.9	0.9	7.0	7.0	2	-	-
546	45-65	Bm	6.5	1	0.1	0.8	6	-	2.8	tr	tr	5.9	1.4	10.1	10.3	16	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
543	-	-	-	-	-	4.6	93	40	-
544	SiL	-	30	64	6	2.3	59	19	-
545	SL	-	53	37	10	0.9	26	7.5	-
546	SiL	-	33	59	8	1.8	59	14	-

Location:	T-42, E. of Twin Cairn, 51°04'48, 115°47'50
Elevation:	7590 feet A.M.S.L.
Slope:	15%
Aspect:	Southeast
Drainage Class:	Rapidly drained
Parent Material:	15 cm aeolian/Glacial till
Vegetation:	*Salix arctica - Antennaria* community
Soil Classification:	Alpine Dystric Brunisol
Remarks:	The solum appears to be somewhat churned up due to downslope creep.

Horizon	Depth (cm)	
L	4-0	Fibrous turf; abrupt, smooth boundary
Ah	0-7	Very dark brown (10YR 2/2 m), very dark grayish brown (10YR 3/2 d) loam; weak, fine granular; very friable; plentiful, fine random roots; clear, wavy boundary; 5 to 12 cm thick; pH 5.6.
Bm	7-11	Dark reddish brown (5YR 3/4 m), brown (10YR 4/3 d) silt loam; weak, fine granular; very friable; plentiful, fine random roots; clear, broken boundary; 0 to 6 cm thick; pH 5.6.
IIBC	11-19	Brown (7.5YR 5/4 m), pale brown (10YR 6/3 d) gravelly sandy loam; moderate, fine subangular blocky; friable; few, fine vertical roots; 25% coarse fragments; gradual, smooth boundary; 8 to 10 cm thick; pH 5.3.
IIC1	19-75	Brown (10YR 4/3 m), light brownish gray (10YR 6/2 d) gravelly loam; fragmental; friable; 40% coarse fragments; pH 5.4.
IIC2	75+	Brown (10YR 4/3 m), light brownish gray (10YR 6/2 d) gravelly loam; fragmental; very firm; pH 5.5.

T-42 CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70547	0-7	Ah	5.6	17	1.0	9.9	10	-	12.6	0.1	0.2	14.2	2.3	29.4	42.3	8	0.99	0.60
548	7-11	Bm	5.6	10	0.5	5.6	11	-	16.7	0.1	0.1	0.6	0.2	17.7	34.4	2	1.07	1.26
549	11-19	IIBC	5.3	2	0.1	1.0	9	-	5.7	tr	tr	1.4	0.2	7.3	11.0	1	0.71	0.20
550	19-75	IIC1	5.4	-	-	-	-	-	4.0	tr	tr	1.9	0.7	6.6	9.2	0	-	-
551	75-90	IIC2	5.5	-	-	-	-	-	3.0	tr	tr	1.8	0.6	5.4	9.2	1	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
547	SiL	-	30	57	13	5.5	100	-	0.4
548	SiL	-	30	62	8	4.4	78	26	0.6
549	SL	25	53	38	9	0.9	28	10	-
550	L	40	46	36	18	1.0	28	9.2	-
551	L	-	53	33	14	0.6	27	8.3	-

Location:	T-43, E. of Twin Cairn Mtn., 51°04'30, 115°47'35
Elevation:	7610 feet A.M.S.L.
Slope:	Level
Aspect:	
Drainage Class:	Very poorly drained
Parent Material:	Alluvium
Vegetation:	*Eriophorum angustifolium* community
Soil Classification:	Orthic Humic Gleysol
Remarks:	This plot is located in an area that experiences considerable groundwater discharge and snowmelt runoff. The center of the basin is about 5 feet higher than the edges, where most of the water runs. Hummocks are as much as 30 cm high with the peat being 10 cm deep. Bgl horizon is reduced, Bg2 is oxidized - indicating oxygenetated water flowing through Bg2.

Horizon	Depth (cm)	
Of	10-0	Dark reddish brown (5YR 3/3 m), dark brown (10YR 3/3 d) slightly decomposed mosses and sedges; sharp, smooth boundary; pH 5.1.
Ahg	0-10	Very dark gray (N3/ m) silt loam; few, fine, faint mottles; amorphous; sticky; plentiful, fine vertical roots; gradual, smooth boundary; pH 7.2.
Bgl	10-20	Gray (N5/ m), grayish brown (2.5Y 5.5/2 d) silt loam; few, fine prominent light olive brown (2.5Y 5/4) mottles; amorphous; very sticky; very few, fine vertical roots; gradual; wavy boundary; pH 4.7.
Bg2	20-50+	Olive gray (5Y 4/2 m), light yellowish brown (2.5Y 6/4 d) silt loam; many, coarse, prominent dark yellowish brown (10YR 4/4) mottles; amorphous, very sticky; 10% coarse fragments; pH 7.4.

T-43 CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70562	10-0	Of	5.1	56	0.8	32.5	43	-	26.6	0.1	1.4	41.2	18.8	88.1	78.8	18	-	-
563	0-10	Ahg	7.2	13	0.8	7.6	10	3.5	-	tr	0.1	31.5	8.1	39.7	48.3	3	-	-
564a	10-20	Bg1	4.7	7	0.4	4.1	10	-	8.6	0.1	0.1	12.6	5.3	26.7	20.2	4	-	-
564b	20-50	Bg2	7.4	.3	0.1	0.2	3	8.9	-	0.0	0.1	8.8	5.2	14.1	7.3	0	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
562		-	-	-	-	-	150	68	-
563	SiL	-	25	66	9	5.1	79	33	-
564a	SiL	-	19	57	24	2.5	100	20	-
564b	Sil	10	20	60	20	0.9	38	10	-

Location:	T-44, N. of Rock Isle Lake, 51°03'55, 115°47'10
Elevation:	7540 feet A.M.S.L.
Slope:	27%
Aspect:	Southeast
Drainage Class:	Rapidly drained
Parent Material:	Colluvium
Vegetation:	*Anemone occidentalis* community
Soil Classification:	Cumulic Regosol (II)
Remarks:	Active downslope movement has resulted in a cumulic, churned-up profile. Rocks turning while sliding cause mixing of horizons.

Horizon	Depth (cm)	
L	1-0	Fibrous turf; abrupt, wavy boundary.
AC	0-2	Very thin, discontinuous horizon.
Ahb	2-3	Very thin, discontinuous horizon.
Ah	3-18	Dark brown (10YR 3/3 m, 4/3 d) loam; weak, fine granular; friable; few, fine vertical roots; clear, wavy boundary; pH 5.5.
A+B+C	18-45	Very dark grayish brown (10YR 3/2 m), yellowish brown (10YR 5/4, 5/6 m), and brown (7.5YR 5/4 m) loam; fragmental; friable to firm; very few, fine vertical roots to 30 cm; gradual, wavy boundary.
C	45+	Yellowish brown (10YR 5/4 m) stoney loam; moderate, fine subangular blocky; friable to firm.

ALTERNATE PROFILE

L	1-0	Fibrous turf; abundant, fine random roots; clear, wavy boundary.
A+B1	0-12	Dark brown (10YR 4/3 m), brown (10YR 5/3 d) silt loam; plentiful, fine vertical roots; less than 10% coarse fragments; gradual, wavy boundary; pH 5.3.
A+B2	12-24	Dark brown (10YR 3/3 m), brown (10YR 5/3 d) loam; moderate, fine, granular; friable; few, fine vertical roots; 10% coarse fragments; gradual, wavy boundary; pH 6.1.

- continued -

T-44 (continued)

Horizon	Depth (cm)	
A+B3	24-39	Dark yellowish brown (10YR 3/4 m), brown (10YR 5/3 d) silt loam; moderate, fine granular; friable; few, fine vertical roots; gradual, wavy boundary; pH 6.1.
C	39+	Roots to 70 cm.

T-44 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70609	3-18	Ah	5.5	10	0.5	5.7	11	-	12.4	tr	0.2	0.6	0.4	13.6	26.4	15	-	-
610	0-12*	A+B1	5.3	4	0.2	2.6	11	-	8.1	tr	0.1	0	0.1	8.3	15.6	18	-	-
611	12-24*	A+B2	6.1	4	0.2	2.2	11	-	5.1	tr	0.1	3.9	0.4	9.5	14.8	14	-	-

* Sample from alternate pit

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
609	SiL	-	28	62	10	3.5	58	23	-
610	SiL	10	27	59	14	2.3	48	14	-
611	SiL	10	26	61	13	2.5	47	13	-

Location:	T-45, N. of Twin Cairn Mtn. 51°05'16, 115°48'02
Elevation:	7450 feet A.M.S.L.
Slope:	Level
Aspect:	
Drainage Class:	Very poorly drained
Parent Material:	Alluvium
Vegetation:	*Eriophorum scheuchzeri* community
Soil Classification:	Orthic Humic Gleysol
Remarks:	This plot is located in a basin that has considerable groundwater discharge as well as runoff from large snowbed accumulations. The plot is located in the streambed.

Horizon	Depth (cm)	
Agh	0-18	Very dark gray (N3/ m), olive (5Y 5/3 d) loam; amorphous; sticky; few, fine vertical roots; 15% coarse fragments; gradual, wavy boundary; 12 to 25 cm thick; pH 6.4.
Bg	18-48	Dark yellowish brown (10YR 4/4 m), light yellowish brown (10YR 6/4 d) gravelly loam; amorphous, sticky; very few, fine vertical roots; 30% coarse fragments; pH 7.4.
IICkg	48+	Brown (10YR 4/3 m) and dark grayish brown (2.5Y 4/2 m), light yellowish brown (2.5Y 6/4 d) very gravelly sandy loam; single grain; loose moderately effervescent; pH 7.9.

T-45 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g H	Na	K	Ca	Mg	SUM	TEC	Avail P ppm	Oxalate Fe %	Oxalate Al %
R70537	0-18	Ahg	6.4	1	0.1	0.6	6	-	1.2	0.1	0.1	6.0	1.4	8.8	8.2	1	-	-
538	18-48	Bg	7.7	tr	tr	tr	0.5	5.8	-	-	-	-	-	-	5.0	0	-	-
539	48-60	IICkg	7.9	0.1	tr	0.1	-	8.2	-	-	-	-	-	-	4.0	0	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm Sand 2-.05	Silt .05-.002	Clay <.002	Moisture Retention % A.D.	1/10 atm	15 atm	Bulk Dens g/cm^3
537	L	15	36	48	16	0.9	32	14	-
538	L	30	43	37	20	0.3	11	8.9	-
539	SL	-	62	25	13	0.5	22	9.1	-

Location:	T-46, N. of Twin Cairn Mtn., 51°04'40, 115°48'10
Elevation:	7480 feet A.M.S.L.
Slope:	0-1%
Aspect:	
Drainage Class:	Very poorly drained
Parent Material:	Alluvium
Vegetation:	*Carex eleusinoides* community
Soil Classification:	Orthic Gleysol
Remarks:	Plot located in an area of groundwater discharge and snowmelt ponding. Carex grows in clumps covering about 50% of the surface.

Horizon	Depth (cm)	
Ahg	0-4	Very dark gray (N3/ m) silty clay loam; moderate, medium subangular blocky; sticky; plentiful, fine vertical roots; less than 5% coarse fragments; clear, irregular boundary; pH 6.1.
Bg	4-20	Light olive brown (2.5Y 5/4 m) silt loam; common, fine distinct, yellowish brown (10YR 5/6 m) mottles; massive, firm; very, few fine vertical roots; less than 5% coarse fragments; gradual, smooth boundary; pH 7.8.
Cg	20+	Gray (5Y 6/1 m) silt loam; many, coarse, prominent yellowish brown (10YR 5/6 m) mottles; massive, slightly sticky; very few, fine vertical roots; less than 5% coarse fragments; pH 8.0.

T-46 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g H	Na	K	Ca	Mg	SUM	TEC	Avail P ppm	Oxalate Fe %	Oxalate Al %
R70494		Ahg	6.1	2	0.1	1.2	8	-	1.1	tr	tr	9.5	5.3	15.9	6.9	1		
495		Bg	7.8	-	tr	0.1	1	20.0	-	-	-	-	-	-	4.3	1		
496		Cg	8.0	-	-	-	-	21.9	-	-	-	-	-	-	3.7	2		

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm Sand 2-.05	Silt .05-.002	Clay <.002	Moisture Retention % A.D.	1/10 atm	15 atm	Bulk Dens g/cm^3
494	L		46	38	16	1.1	35	9.2	
495	SiL		23	58	19	0.3	31	9.5	
496	SiL		13	73	14	0.4	36	8.9	

Location:	T-47, NE flank of Quartz Hill, 51°02'50, 115°46'25
Elevation:	7550 feet A.M.S.L.
Slope:	Level (terrace)
Aspect:	East
Drainage Class:	Rapidly drained
Parent Material:	Colluvium/Bedrock
Vegetation:	*Saxifraga lyallii* community
Soil Classification:	Lithic Alpine Eutric Brunisol (calcareous)
Remarks:	Plot located on small bedrock terrace on side of mountain. Colluvial material perched on terrace. Cobbly surface, very stony profile. B and C are very difficult to separate, probably due to churning by mass wasting processes. Several colors from different rocks weathering. Late snowbed area.

Horizon	Depth (cm)	
Ahk	0-5	Dark gray (10YR 3.5/1 m), grayish brown (10YR 5/2 d) gravelly silt loam; weak, fine granular; very friable; abundant, fine vertical roots; very weakly effervescent; 50% coarse fragments; clear, irregular boundary; 1 to 10 cm thick; pH 7.1.
Bmk	5-15	Dark yellowish brown (10YR 4/4 m), pale brown (10YR 6/3 d) gravelly silt loam; moderate, fine subangular blocky; friable; very few, fine random roots; very weakly effervescent; 30% coarse fragments; diffuse, smooth boundary; 0 to 15 cm thick.
BC	15-25	Yellowish brown (10YR 5/4 m), pale brown (10YR 6/3 d) sandy loam; friable; very weakly effervescent; 0 to 10 cm thick; pH 7.7.
R	25+	Dolomitic chert? Bedrock.

T-47 CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70506	0-5	Ahk	7.1	5	0.3	2.9	11	0.9	-	0.1	0.1	15.8	5.4	21.4	17.7	19	-	-
507	15-25	BC	7.7	1	0.1	0.6	6	1.5	-	-	-	-	-	-	8.6	20	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
506	SiL	50	32	60	8	2.4	73	13	-
507	SiL	-	26	59	15	0.9	37	8.7	-

Location:	T-48, North of Twin Cairn Mtn.
Elevation:	7480 feet A.M.S.L.
Slope:	0 to 1%
Aspect:	
Drainage Class:	Poorly drained
Parent Material:	Alluvium
Vegetation:	*Carex* community
Soil Classification:	Rego Humic Gleysol
Remarks:	Plot located in a snow-melt drainage that is subjected to annual flooding and ponding. Groundwater seepage evident. Slight hummocky micro-relief.

Horizon	Depth (cm)	
L	5-0	Fibrous turf; abundant, fine random roots; abrupt, wavy boundary; 3 to 15 cm thick; pH 6.4.
Ahg	0-25	Olive gray (5Y 4/2 m), grayish brown (2.5Y 5/2 d) sandy loam; weak, fine subangular blocky; friable; few, medium random roots; 5% coarse fragments; diffuse, wavy boundary; 15 to 30 cm thick; pH 6.5
ACg	25-35	Olive gray (5Y 5/2 m) gravelly loam; many, coarse, prominent (10YR 5/6 m), mottles; weak, fine subangular blocky; friable; plentiful, fine vertical roots; 40% coarse fragments; diffuse, smooth boundary.
Cg	35+	Light olive brown (2.5Y 5/4 m), olive yellow (2.5Y 6/5 d) gravelly sandy loam; many, medium, faint (2.5Y 5/2 m) mottles; few, fine vertical roots; 75% coarse fragments; pH 7.7.

T-48 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g H	Na	K	Ca	Mg	SUM	TEC	Avail P ppm	Oxalate Fe %	Oxalate Al %
R70497	5-0	L	6.4	28	1.2	16.6	14	-	8.5	0.2	0.2	24.0	1.3	34.2	10.0	12		
498	0-25	Ahg	6.5	3	0.2	1.6	9	-	2.0	tr	tr	4.0	3.1	9.1	7.5	1		
499	35-50	Cg	7.7	-	-	-	-	14.8	-	-	-	-	-	-	2.7	1		

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm Sand 2-.05	Silt .05-.002	Clay <.002	Moisture Retention % A.D.	1/10 atm	15 atm	Bulk Dens g/cm^3
497	-	-	-	-	-	4.2	130	73	
498	SL	5	55	34	11	0.7	29	8.4	
499	SL	75	58	31	11	0.2	21	5.8	

Location:	T-49, East of Twin Cairn Mtn.
Elevation:	7900 feet A.M.S.L.
Slope:	5 - 18%
Aspect:	Southeast
Drainage Class:	Rapidly drained
Parent Material:	Aeolian/colluvium/till/shale bedrock
Vegetation:	*Cassiope tetragona* community
Soil Classification:	Lithic Alpine Dystric Brunisol
Remarks:	The IIBC is a mixture of material that is probably due to churning by soil creep. The till (IIIC) is very compact. The Ah horizon is present only under the clumps of Cassiope - not between the clumps. Silt coatings were noticed on shale fragments in the profile.

Horizon	Depth (cm)	
L	3-0	Very dark brown (5YR 2/2 m), very dark gray (10YR 3/1 d) fibrous turf; plentiful, fine random and abundant, medium horizontal roots; clear, wavy boundary; 2 to 4 cm thick; pH 5.4.
Ah	0-3	Very dark grayish brown (10YR 3/2 m, 3/2 d) loam; weak, fine granular; very friable; plentiful, fine random roots; clear, irregular boundary; 0 to 5 cm thick; pH 5.5.
Bm	3-11	Dark brown (10YR 3/3 m),grayish brown (10YR 5/2 d) silt loam; weak, fine granular; very friable; few, fine random roots; abrupt, wavy boundary; 7 to 10 cm thick; pH 6.3.
IIBC	11-31	Yellowish brown (10YR 5/6 m), dark yellowish brown (10YR 4/4 m), very dark grayish brown (10YR 3/2 m), yellowish red (5YR 4/6 m) and pale brown (crushed) (10YR 5.5/3 d) silt loam; moderate, fine subangular blocky; friable; very few, fine random roots; 20% coarse fragments; clear, wavy boundary; pH 6.6.
IIIC	31-46	Dark gray (10YR 4/1 m), pale brown (10YR 6/3 d) shaley loam; fragmental; firm; 30% coarse fragments; abrupt, irregular boundary; 12 to 20 cm thick; pH 6.9.
R	46+	Shale bedrock.

T-49 CHEMICAL

Sample Number	Depth (cm)	Hori- zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70552	3-0	L	5.4	36	1.6	21.0	13	-	16.1	0.3	3.4	24.4	3.7	47.9	69.7	45	-	-
553	0-3	Ah	5.5	26	1.1	14.9	13	-	6.9	0.2	0.5	15.1	4.4	27.1	47.0	7	0.79	0.50
554	3-11	Bm	6.3	11	0.4	6.3	16	-	5.1	tr	0.1	10.6	3.1	18.9	25.1	1	0.96	1.12
555	11-31	IIBC	6.6	2	0.1	1.2	10	-	2.0	tr	0.1	12.8	5.7	20.6	15.7	0	0.87	0.18
556	31-46	IIIC	6.9	-	-	-	-	-	0.8	tr	0.1	8.3	3.8	13.0	8.8	0	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
552		-	-	-	-	5.9	120	82	0.6
553		-	-	-	-	7.5	110	45	-
554	SiL	-	23	67	10	4.3	71	17	0.8
555	SiL	20	20	55	25	1.9	28	12	1.2
556	L	30	36	40	24	0.8	28	9.8	1.8

Location:	T-50, East of Twin Cairn Mtn.
Elevation:	7730 feet A.M.S.L.
Slope:	30%
Aspect:	Southeast
Drainage Class:	Rapidly drained
Parent Material:	20 cm Colluvium + Aeolian/30 cm Colluvium/Till
Vegetation:	*Vaccinium scoparium*
Soil Classification:	Alpine Dystric Brunisol
Remarks:	Mass wasting processes on this unstable slope result in buried horizons and distortion of horizon orientation.

Horizon	Depth (cm)	
L	6-0	Fibrous turf; abundant; fine random and abundant, medium horizontal roots; abrupt, wavy boundary; 4 to 8 cm thick; pH 5.2.
Ah1	0-1	Very dark grayish brown (10YR 3/2 m), dark grayish brown (10YR 4/2 d) loam; weak, fine granular; friable; plentiful, fine random and abundant, medium horizontal roots; 10% coarse fragments; clear, broken boundary; 0 to 1 cm thick; pH 5.5.
Bm1	1-4	Dark yellowish brown (10YR 4/4 m) shaley silt loam; weak, fine granular; loose; plentiful, fine random and abundant, medium horizontal roots; 30% shale fragments; clear, broken boundary; 0 to 7 cm thick.
Ah2	4-7	Dark brown (10YR 3/3 m) loam; weak, medium granular; very friable; plentiful, fine random and abundant, medium horizontal roots; 10% shale fragments; clear, wavy boundary; 1 to 7 cm thick.
Bm2	7-13	Dark yellowish brown (10YR 3/4 m), brown (10YR 4/3 d) silt loam; weak, medium subangular blocky; friable; abundant; fine random roots; 5 to 15% coarse fragments; clear, wavy boundary; 5 to 10 cm thick; pH 6.1.
IIBm3	13-21	Strong brown (7.5YR 5/6 m) gravelly sandy loam; moderate, fine granular; friable; few, fine vertical roots; 50% shale fragments; gradual, wavy boundary; 5 to 10 cm thick; pH 6.2.

- continued -

T-50 (continued)

Horizon	Depth (cm)	
IIBm4	21-29	Brown (10YR 4/3 m) very shaley sandy loam; fragmental; loose; few, fine vertical roots; 30 to 80% shale fragments; gradual, wavy boundary; 5 to 12 cm thick; pH 6.2.
IIBm5	29-37	Dark brown (7.5YR 4/4 m) gravelly sandy loam; moderate, medium subangular blocky; friable; 30% coarse fragments; clear, broken boundary; 0 to 13 cm thick; pH 6.2.
IIIC	37+	Dark grayish brown (10YR 4/2 m), pale brown (10YR 6/3 d) gravelly loam; fragmental; friable to firm.

T-50 CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70557	6-0	L	5.2	42	2.3	27.4	12	-	26.7	0.7	3.2	41.9	7.4	79.9	86.5	56	-	-
558	0-1	Ah1	5.5	13	0.5	7.8	15	-	9.5	tr	0.3	12.2	2.0	24.0	26.1	4	0.72	0.23
559	7-13	Bm2	6.1	7	0.4	4.3	12	-	6.7	.1	0.1	5.9	2.0	14.8	22.0	1	0.87	0.92
560	21-29	IIBm4	6.2	1	0.1	0.8	10	-	2.6	tr	0.1	3.4	2.5	8.6	9.8	1	0.45	0.20
561	37-50	IIIC	5.9	-	-	-	-	-	2.0	tr	0.1	2.9	1.5	6.5	7.2	1	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
557		-	-	-	-	10.2	150	106	-
558	SiL-L	10	33	50	17	2.5	59	28	-
559	SiL	5-15	40	54	6	3.6	57	15	-
560	SL	30-80	49	41	10	1.0	32	7.4	-
561	L		40	45	15	0.9	28	7.1	-

Location: T-51, Standish Hump, 51°04'01, 115°47'10

Elevation: 7560 feet A.M.S.L.

Slope: 0-1%

Aspect:

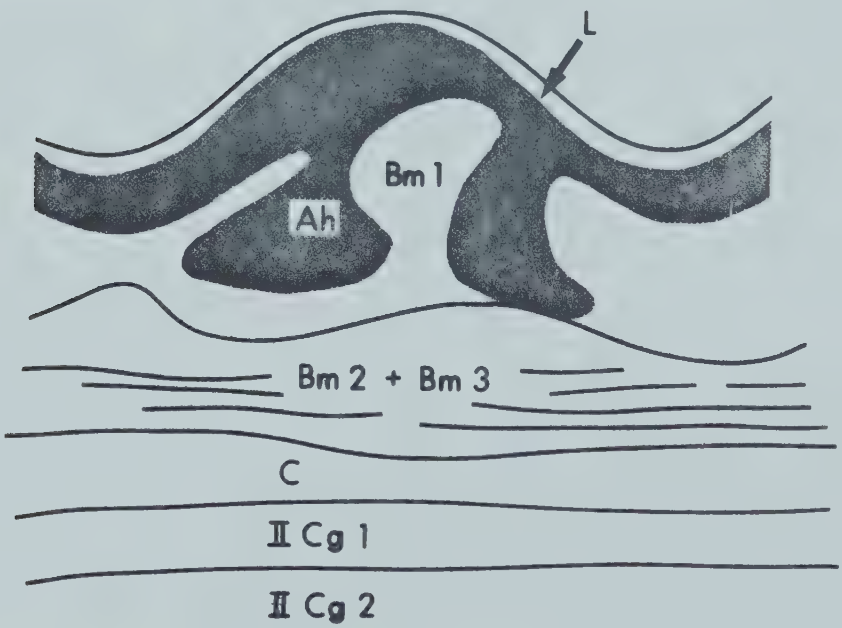
Drainage Class: Imperfectly drained

Parent Material: Aeolian (volcanic ash)/Lacustrine

Vegetation: *Carex nigricans* community

Soil Classification:

Remarks: Plot located in a small enclosed basin 2/3 of the way up Standish Hump. Silt bands in Bm3 not well developed. Profile very similar to T-23, 24, and 25.



Profile Sketch (1/10 scale)

T-51 (continued)

Horizon	Depth (cm)	
L		Turf.
Ah		
Bm1		Profile description same as for T-23, T-24, T-25.
Bm2 and Bm3		
C	50	
IICG1		
IICg2		

T-51 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70612		Ah	5.5	13	0.4	7.4	18	-	11.3	0.1	0.1	0.5	0.2	12.2	-	3	0.71	0.76
613		Bm1	5.8	11	0.5	6.1	12	-	13.9	0.2	0.1	0	0.2	14.4	35.7	3	1.13	3.48
614		Bm2 + Bm3	6.0	5	0.2	2.8	11	-	6.4	0.1	tr	0	0.1	6.6	17.8	6	0.66	3.06

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
612	SiL	-	15	70	15	3.2	76	23	-
613	SiL	-	23	72	5	6.7	100	26	-
614	SiL	-	23	74	3	9.0	85	23	-

Location:	T-52, North of Quartz Hill, 51°02'45, 115°46'27
Elevation:	7865 feet A.M.S.L.
Slope:	12%
Aspect:	
Drainage Class:	Well drained
Parent Material:	Colluvium/Bedrock
Vegetation:	*Kobresia myosuroides* community
Soil Classification:	Lithic Alpine Eutric Brunisol (calcareous)
Remarks:	The turfy L is tussocky being up to 6-8 cm thick under tussocks. Profile varies from Ah, Rock; to Ah, Bm, C, Rock sequence.

Horizon	Depth (cm)	
L	3-0	Fibrous turf; abundant, fine random roots; gradual, wavy boundary; 1 to 6 cm thick.
Ah	0-10	Very dark brown (10YR 2/2 m), very dark grayish brown (10YR 3/2 d) silt loam; weak, fine granular; very friable; plentiful, fine vertical roots; clear, wavy boundary; 7 to 12 cm thick; pH 7.6.
Bmk	10-16	Dark brown (10YR 3/3 m) gravelly loam; moderate, fine subangular blocky; friable; plentiful, fine vertical roots; weakly effervescent; 50% coarse fragments; gradual, broken boundary; 0 to 7 cm thick.
Ck	16-25	Dark brown (10YR 4/3 m), pale brown (10YR 6/3 d) gravelly silt loam; fragmental; friable; very few, fine vertical roots to bedrock; weakly effervescent; 50% coarse fragments; abrupt, broken boundary; 0 to 20 cm thick; pH 7.9.
R	25+	Limestone bedrock (occurs at depths varying from 6 to 30 cm).

T-52 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70630	0-10	Ah	7.6	19	1.0	11.1	11	0.4	-	-	-	-	-	-	59.7	3	-	-
631	16-25	Ck	7.9	-	-	-	-	11.7	-	-	-	-	-	-	12.9	29	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
630	SiL	-	27	65	8	5.8	110	43	-
631	SiL	50	25	59	16	1.4	42	9.8	-

Location:	T-53, Quartz Ridge, 51°03'10, 115°46'32
Elevation:	7540 feet A.M.S.L.
Slope:	4%
Aspect:	
Drainage Class:	Well drained
Parent Material:	
Vegetation:	*Salix nivalis* community
Soil Classification:	
Remarks:	Profile described and sampled by H. Samoil.

T-53 CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail P ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70828		L	5.8	51	1.9	29.5	-	-	19.8	0.1	2.5	67.5	17.6	107.5	-	36	-	-
829		Ah	7.4	11	0.4	6.0	16	10.4	-	-	-	-	-	-	-	4	0.52	0.28
830		?	7.7	8	0.3	4.5	17	0.8	-	-	-	-	-	-	-	4	0.53	0.42
831		?	7.7	-	-	-	-	0.4	-	-	-	-	-	-	-	2	0.81	0.49

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
828	-		-	-	-	9.4	160	8.3	
829	L		36	45	19	3.5	64	20	
830	SiL		23	67	10	3.0	83	87	
831	L		34	47	19	2.6	44	18	

Location:	T-54, N. of Quartz Hill, 51°02'44, 115°46'31
Elevation:	8000 feet A.M.S.L.
Slope:	10-15%
Aspect:	South
Drainage Class:	Well drained
Parent Material:	Aeolian + colluvium/Glacial till
Vegetation:	*Cassiope tetrangona* community
Soil Classification:	Orthic Regosol
Remarks:	The Ah is very black. Downslope soil creep evidenced by irregular contact between A and C horizons. There are lenses and pockets of brownish ash in the lower Ah. Moisture availability may be quite high due to snowbanks and possible groundwater seepage early in summer.

Horizon	Depth (cm)	
L	2-0	Very dark brown (10YR 2/2 m), very dark gray (10YR 3/1 d) fibrous turf; abundant, fine random and abundant, medium horizontal roots; clear, wavy boundary; 1 to 4 cm thick; pH 6.3.
Ah	0-12	Black (10YR 2/1 m), very dark gray (10YR 3/1 d) silt loam; weak, fine granular; friable; plentiful, fine random roots; abrupt, wavy boundary; 10 to 15 cm thick; pH 6.7.
AC	12-17	Dark brown (10YR 3/3 m) silt loam; gradual, broken boundary; 0 to 10 cm thick.
IICk	17+	Dark brown (10YR 4/3 m), pale brown (10YR 6/2.5 d) silt loam to very gravelly silt loam; moderate, fine subangular blocky; friable; very few, fine vertical roots to 25 cm; moderately effervescent; pH 7.7.

T-54 **CHEMICAL**

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g H	Na	K	Ca	Mg	SUM	TEC	Avail P ppm	Oxalate Fe %	Oxalate Al %
R70624	2-0	L	6.3	64	1.5	37.0	24	-	14.8	0.2	1.1	91.2	6.8	114.1	105.0	5	-	-
625	0-12	Ah	6.7	36	1.4	20.8	14	-	5.2	tr	0.1	87.5	7.7	100.5	93.5	0	-	-
626	17-30	IICk	7.7	-	-	-	-	0.5	-	-	-	-	-	-	13.9	4	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm Sand 2-.05	Silt .05-.002	Clay <.002	Moisture Retention % A.D.	1/10 atm	15 atm	Bulk Dens g/cm^3
624	-		-	-	-	11	210	91	-
625	-		-	-	-	9.4	200	70	-
626	SiL		20	57	23	1.3	39	11	-

Location:	T-55, Quartz Hil, $51^{o}02'18$, $115^{o}46'01$
Elevation:	8300 feet A.M.S.L.
Slope:	50%
Aspect:	Southeast
Drainage Class:	Rapidly drained
Parent Material:	Colluvium (with aeolian inclusions)
Vegetation:	*Kobresia myosuroides* community
Soil Classification:	Alpine Eutric Brunisol (calcareous)
Remarks:	Kobresia turf grows in tussocky micro-relief. The Ah is very black and thick with a low bulk density. Most pebbles appear to be quartzites; however, there are lime accumulations on the undersides of rocks in the C horizon.

Horizon	Depth (cm)	
L	4-0	Fibrous turf; abundant, fine random roots; gradual, wavy boundary; 2 to 7 cm thick.
Ahk	0-15	Black (10YR 3/1 m), very dark gray (10YR 3/1 d) loam; moderate, medium granular; very friable; abundant, fine vertical roots; very weakly effervescent; 5% coarse fragments; gradual, wavy boundary; 10 to 20 cm thick; pH 7.3.
Bmk	15-18	Yellowish brown (10YR 5/6 m) silt loam; weak, fine granular; very friable; plentiful, fine vertical roots; very weakly effervescent; 10 to 15% coarse fragments; abrupt, broken boundary; 0 to 5 cm thick; pH 7.6.
IIC	18-50+	Dark grayish brown (10YR 4/2 m), grayish brown (10YR 5/2 d) very gravelly sandy loam; few, fine vertical roots to 40 cm; weakly effervescent; 80% coarse fragments; pH 7.5.

T-55 CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70618	0-15	Ahk	7.3	17	0.8	10.0	12	0.5	-	tr	0.2	39.0	5.6	44.8	44.2	1	0.33	0.52
619	15-18	Bmk	7.6	8	0.5	4.4	9	0.6	-	-	-	-	-	-	30.9	2	0.35	1.22
620	18-50	IIC	7.6	-	-	-	-	-	-	-	-	-	-	-	10.2	16	0.17	0.24

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
618	L	5	42	47	11	4.9	94	38	-
619	SiL	10-15	45	53	2	3.5	86	19	-
620	SL	80	72	20	8	0.9	24	6.4	-

Location:	L-1. East side of Wa-Wa Ridge
Elevation:	7700 feet A.M.S.L.
Slope:	15%
Aspect:	East-southeast
Drainage Class:	Rapidly drained
Parent Material:	Colluvium/Till
Vegetation:	*Phyllodoce glanduliflora, Antennaria lanata, Salix arctica, Vaccinium scoparium*
Soil Classification:	
Remarks:	This plot is located on a terrace of Wa-Wa Ridge, terrace probably due to bedrock control. Ah, Ahe, Bm in colluvium, IIBC and IIC in till. Bulk densities and thin sections taken. Bm is very variable as to organic content.

Horizon	Depth (cm)	
L	2-0	Very dark grayish brown (10YR 3/2 d) densely-rooted turf; abundant, fine and medium horizontal roots; and abundant, fine vertical roots; less than 5% coarse fragments; clear, wavy boundary.
Ah	0-5	Dark brown (10YR 3/3 m), dark grayish brown (10YR 4/2 d) loam; moderate, fine granular; friable; abundant, fine random roots; clear, wavy boundary; 3 to 6 cm thick; pH 4.7.
Ahe	5-9	Brown (10YR 4/3 m, 5/3 d) loam; weak, fine granular; very friable; plentiful, fine random roots; less than 5% coarse fragments; gradual, wavy boundary; 3 to 5 cm thick; pH 5.0.
Bm	9-17	Dark brown (7.5YR 4/4 m), yellowish brown (10YR 5/6 d) silt loam; moderate, fine granular; friable; plentiful, fine random roots; less than 5% coarse fragments; clear, wavy boundary; 5 to 10 cm thick; pH 5.4.
IIBC	17-24	Yellowish brown (10YR 5/4 m), light yellowish brown (10YR 6/4 d) loam; moderate, medium fine granular; friable; very few, fine random roots; 10% coarse fragments; gradual, smooth boundary; 5 to 12 cm thick; pH 5.3.
IIC	24-56+	Olive brown (2.5Y 4/4 m), light brownish gray (10YR 6/2 d) loam; fragmental; firm; very few, fine random roots; 15% gravel; pH 5.5.

L-1 CHEMICAL

Sample Number	Depth (cm)	Hori-zon	H_2O pH	O.M. %	N %	Org. C %	C/N	$CaCO_3$ Equiv. %	Exchange Analysis me/100g							Avail p ppm	Oxalate	
									H	Na	K	Ca	Mg	SUM	TEC		Fe %	Al %
R70528	0-5	Ah	4.7	22	0.9	12.7	15	-	20.8	0.3	0.9	3.3	1.3	26.6	35.8	15	-	-
529	5-9	Ahe	5.0	8	0.3	4.5	14	-	12.6	0.1	0.1	0.5	0.4	13.7	21.5	2	0.96	0.40
530	9-17	Bm	5.4	7	0.3	4.2	14	-	12.5	0.1	0.1	0.2	0.3	13.2	25.7	0	1.41	1.60
531	17-24	IIBC	5.3	0.7	0.1	0.4	5	-	5.4	0.1	tr	0	0.2	5.7	9.0	1	0.62	0.30
532	24-50	IIC	5.5	-	-	-	-	-	3.0	tr	tr	1.5	1.0	5.5	7.7	1	-	-

PHYSICAL

Sample Number	Text. Class	% >2mm est.	Particle Size Distribution (mm) % of <2mm			Moisture Retention %			Bulk Dens g/cm^3
			Sand 2-.05	Silt .05-.002	Clay <.002	A.D.	1/10 atm	15 atm	
528	SL		69	29	4	4.6	72	34	0.6
529	L	5	41	49	10	-	48	17	-
530	SiL	5	29	58	13	4.3	54	20	0.8
531	L	10	41	41	18	1.2	23	9.4	-
532	L	15	42	38	20	6.3	25	8.8	1.6

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